A BIOMECHANICAL ANALYSIS OF TRUNK MOTION DURING STAIR DESCENT IN TOTAL AND UNICOMPARTMENTAL KNEE ARTHROPLASTY PATIENTS COMPARED TO HEALTHY CONTROLS

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INTRODUCTION

Osteoarthritis (OA) is a chronic degenerative joint disease commonly affecting the knee joint in approximately 12.2% of elderly people over the age of 60 [1]. Symptomatic knee OA causes debilitating pain and may lead to walking gait abnormalities including a reduced stride length, walking speed, and pelvic rotation and increased lateral trunk motion [2, 3]. Knee OA has resulted in a rapid increase in total knee arthroplasty (TKA) [4]and unicompartmental knee arthroplasty (UKA) [5], with both surgical interventions effectively improving patient function [6, 7].

Total knee arthroplasty is a widely accepted surgical intervention for moderate to severe OA that replaces the entire knee joint with the primary goal of reducing knee pain [5, 8, 9]. Despite the success of surgical intervention in pain reduction and the implementation of traditional rehabilitation programs, post-TKA functional limitations remain. These can include lower extremity muscle weakness [2, 5], decreased range of motion (ROM) [4], difficulty with stair negotiation [2, 5] and reduced knee proprioception [4]. The surgical process of UKA involves the replacement of osteoarthritis that is limited to one compartment [10-12]. Research suggests that with the preservation of soft tissue and both cruciate ligaments, UKA produces significantly better postoperative outcome measures than TKA and patients present with a walking gait that more closely resembles normal gait patterns [6, 7, 10, 12-17].

Stair descent is considered one of the most difficult activities to accomplish during the early stages of knee OA and functional limitations remain after surgery [18, 19]. The ability to functionally descend stairs is of particular importance due to the prevalence of falls during stair negotiation in elderly and TKA patients [19, 20]. In elderly people, poor proprioception of the trunk can cause incorrect foot positioning during normal gait leading to frontal plane trunk instability and increases in risks of falling [21]. While UKA and TKA patients have demonstrated similar knee kinematics during stair descent [13], to our knowledge, there are limited biomechanical research studies evaluating the post-operative trunk motion in both TKA and UKA patients during stair descent. The purpose of this research study was to compare sagittal and frontal plane trunk motion during stair descent in post-operative TKA and UKA patients to healthy controls. It was hypothesized that TKA patients would exhibit increased post-operative sagittal and frontal compensatory trunk motion compared to UKA patients and healthy controls. It was also hypothesized that sagittal and frontal plane trunk motion in UKA would more closely resemble that of healthy controls.

METHODOLOGY

Research Design

A longitudinal design was utilized to investigate the effectiveness of a UKA implant design when compared to a TKA implant group and healthy aged-matched control group. Biomechanical assessment of OA patients during stair negotiation occurred within one week prior to surgery and post-surgically at six-weeks, three-months, six-months and one-year. Healthy control participants completed a single biomechanical assessment to be used for comparison of biomechanical variables of interest to knee arthroplasty patients.

Participants

Inclusion criteria for all TKA and UKA patients consisted of: under 75 years of age, no previous history of lower extremity fracture, osteotomy, or joint replacement, undergoing a unilateral or bilateral UKA or TKA for the treatment of osteoarthritis, and physically able to walk without an aid. Total Knee Arthroplasty patients (18 patients, 12 unilateral, 6 bilateral) were screened for inclusion of this study and randomly assigned to receive either a single radius (SR) (GetAroundKnee™, Stryker Orthopedics, Mahwah,NJ) or a multi-radius (MR) implant (Balanced Knee® System, Ortho Development Corporation, Draper, UT) design. All UKA patients (7 patients, 5 unilateral, 2 bilateral) were screened for inclusion and received an Oxford® Partial Knee Implant (Zimmer Biomet Orthopedics, Warsaw, IN). All TKA and UKA surgeries were performed by the same board certified orthopedic surgeon. Total knee arthroplasty patients were compared to 25 healthy aged-matched controls and UKA patients were compared to 9 healthy aged-matched controls. Biomechanical assessment of enrolled arthroplasty patients occurred within one week prior to surgery and post-surgery at six-weeks, three-months, six-months and one-year. Inclusionary criteria for controls included: ages between 55-75 with no previous history of heart conditions, balance or fainting disorders, Parkinson's Disease, diagnosed neurological disorders, diabetes mellitus, rheumatoid arthritis, osteoarthritis, surgery to the hip, knee or ankle or injury or severe knee pain in the last six months. Data were collected on healthy control participants in the same manner on the right limb only at a one-time data collection. Participants were excluded from the study if: an implant revision was required, had a primary residence on an island other than on the island of Oahu, became pregnant before or during the study, or developed any pathology or injury that required cessation of activity.

Participants completed an informed consent process and signed consent form approved by the University's Human Studies Program (Appendix A). Each participant was de-identified and received an ID number that was used for all data collection sessions and paperwork. All participant data were kept in a filing cabinet in a locked office within the Biomechanics Human Performance Lab at the University of Hawaiʻi at Mānoa.

Procedures

All biomechanical analyses will be conducted at the University of Hawaiʻi Gait Laboratory. Control participants completed a health questionnaire to determine eligibility to participate in this study (Appendix B). Following completion of the surveys, the participant's height was collected using a wall-mounted stadiometer and reported in millimeters (Model 67032, Seca Telescopic Stadiometer, Country Technology, Inc., Gays Mills, WI, USA) and body mass using a Detecto certifier scale and reported in kilograms (Webb City Mo, USA). Shank lengths were recorded as the distance measured from the lateral knee joint line to the distal lateral malleolus; 80% of shank length will be calculated and marked. These markings served as location points for placement of the hand-held dynamometer during knee extensor strength testing, which allowed for consistent placement of the dynamometer relative to each patient.

Twenty-nine reflective markers were placed bilaterally over: anterior superior iliac spines, posterior superior iliac spines, medial and lateral femoral condyles, medial and lateral malleoli, calcanei, base and head of the fifth metatarsals, head of the first and second metatarsals and acromioclavicular joints. Rigid marker arrays were placed bilaterally on lateral thighs and shanks. Single reflective markers were placed over: xyphoid process, superior aspect of manubrium at the jugular notch, vertebral spinous process of cervical seven, thoracic vertebral spinous process of thoracic ten and the inferior angle of the right scapula. Markers on the medial femoral epicondyle, medial malleolus and head of the first metatarsal were used for calibration purposes during a static trial only and were removed for stair trials.

A three-step staircase, with dimensions of an 18cm step rise, 46cm step width and 28cm step tread were used for assessing stair negotiation. Each participant began walking at a self-selected velocity descending the stairs using a reciprocal foot-fall pattern with the surgical limb contacting the second-step and ground. Patients were provided a handrail for safety but were instructed not to use it unless balance was compromised. The trial was discarded if the handrail was used. A member of the research team was positioned at the bottom of the stairs at all times to provide further assistance if needed. Marker positions were collected during stair negotiation trials using a Vicon Nexus motion capture system (Vicon, Inc., Centennial, CO). Two force plates (Advanced Mechanical Technology Incorporated, Boston, MA), one embedded flush with the floor and one instrumented within the second step of the stairs, were used to collect kinetic data. Kinematic data were collected at 240 Hz and time synchronized with kinematic data collected at 960 Hz. A low-pass Butterworth filter was used to filter kinematic data and kinetic data used for calculation of external joint moments at a 10 Hz cut-off frequency and ground reaction force data was filtered using a 50 Hz cut-off frequency. Joint moments were calculated using inverse dynamics based on filtered marker trajectories and kinetic data. All data was processed using Visual 3D (C-Motion, Inc., Germantown, MD). Due to high intra-subject variability previously reported during stair climbing in the OA population, five successful trials were averaged.

Bilateral knee extensor muscle strength tests were performed using a handheld dynamometer following stair descent trials (Hoggan Health Industries, West Jordan, UT). Hip abductor strength was tested while the patient was side-lying, with the non-test limb in contact with the table. A pillow was placed between the patient's knees for support and to ensure a starting position of 0° hip abduction. The dynamometer was placed on the mark indicating 80% of the femur length and was secured in place with a strap. The patient was instructed to abduct the hip while maintaining an extended hip and knee. Knee extensor strength was performed with the patient seated in a recumbent position with their knee flexed to 65° and their trunk extended 130° from the surface of the treatment table with their hands placed on the table behind them supporting their trunk in this position. Placement of the dynamometer was at the marked 80% length of the shank and was secured in place by a strap to ensure constant resistance. Participants were instructed to build a force over three seconds, holding the maximal force contraction for two seconds. Two trials of a three-second maximal effort isometric knee extension contraction were completed. A third trial was completed if the second trial did not measure within 10% force output of the first trial. Verbal encouragement was given to help elicit maximal force production by the participant during strength testing.

Statistical Analysis

Data normality was assessed using Shapiro-Wilk Test and Levene's Test was performed to assess homogeneity of variance among groups for all biomechanical variables of interest. Analysis of variance (ANOVA) was performed to identify significant differences in dependent biomechanical variables between controls, TKA and UKA groups. If significant differences were found in either the Levene's Tests or Shapiro-Wilk Tests, a non-parametric test Mann-Whitney U was performed. A paired Sample T-Test was performed to determine quadriceps and hip abductor strength differences between the operative and non-operative limbs of TKA and UKA patients. All data was analyzed using SPSS Version 22.0 and an alpha level of $p \leq 0.05$ was used to determine statistical significance.

RESULTS

A total of fifty participants were included in the study; eighteen with TKA (24 knees), seven with UKA (9 knees), and twenty-five controls. There were no demographic differences between each group and their means and standard deviations can be found in Table 1.

Table 1.
Participant Demographics

	TKA (N = 18, 24 knees) Mean ± SD	Control (N = 25, 25 knees) Mean ± SD	P Value
Age	65.2 ± 5.2	64.08 ± 6.1	0.487
Height (m)	1.67 ± 87.9	1.70 ± 94.5	0.268
Weight (kg)	81.3 ± 16.6	82.3 ± 16.1	0.829
	UKA (N = 7, 9 knees) Mean ± SD	**Control (N = 9, 9 knees) Mean ± SD**	**P Value**
Age	68.1 ± 3.9	64.08 ± 6.1	0.855
Height (m)	1.69 ± 79.6	1.70 ± 94.5	0.428
Weight (kg)	88.7 ± 18.3	82.3 ± 16.1	0.336
	TKA (N = 18, 24 knees) Mean ± SD	**UKA (N = 7, 9 knees) Mean ± SD**	**P Value**
Age	65.2 ± 5.2	68.1 ± 3.9	0.137
Height (m)	1.67 ± 87.9	1.69 ± 79.6	0.604
Weight (kg)	81.3 ± 16.6	88.7 ± 18.3	0.277

Sagittal trunk lean was greater in the TKA group pre-operatively (TKA = -17.4 degrees, CON = -11.9 degrees, $p = 0.013$) as well as a greater frontal trunk lean pre-operatively (TKA = 7.1 degrees, CON = 1.8 degrees, $p < 0.001$), and post-operatively at six weeks (TKA = 5.9 degrees, CON = 1.8 degrees, $p = 0.003$), three months (TKA = 5.3 degrees, CON = 1.8 degrees, $p = 0.002$), and six months (TKA = 5.0 degrees, CON = 1.8 degrees, $p = 0.01$) in comparison to controls. Less lateral trunk flexion was demonstrated in TKA patients pre-operatively (TKA =

11.6 degrees, CON = 6.6 degrees, $p < 0.001$), at six weeks post-operatively (TKA = 11.7 degrees, CON = 6.6 degrees, $p < 0.001$), three months (TKA = 11.0 degrees, CON = 6.6 degrees, $p < 0.001$), six months (TKA = 9.8 degrees, CON = 6.6 degrees, $p = 0.003$), and at one year (TKA = 8.3 degrees, CON = 6.6 degrees, $p = 0.045$) in comparison to controls. Additionally, TKA patients in comparison to controls had a greater sagittal pelvic tilt at six weeks post-operatively (TKA = -8.2 degrees, CON = 5.3 degrees, $p = 0.007$), and at one year (TKA = -3.6 degrees, CON = 5.3 degrees, $p = 0.03$). The kinematic comparisons between TKA patients and controls can be found in Table 2.

Table 2.
Kinematic Comparisons Between TKA Patients and Controls

	Pre-operative		
	TKA (N = 18, 24 knees) Mean ± SD	Control (N = 25, 25 knees) Mean ± SD	P Value
Sagittal Trunk Lean	-17.4 ± 8.7	-11.9 ± 5.7	0.013
Frontal Trunk Lean	7.1 ± 6.7	1.8 ± 2.4	<0.001[a]
Sagittal Pelvic Tilt	-2.5 ± 16.5	5.3 ± 7.0	0.172[a]
Frontal Pelvic Tilt	-6.9 ± 3.7	-5.5 ± 2.8	0.166
Trunk Flexion	-2.5 ± 5.9	-5.4 ± 10.0	0.130[a]
Lateral Trunk Flexion	11.6 ± 5.6	6.6 ± 2.3	<0.001[a]
	Six Weeks Post-operative		
Sagittal Trunk Lean	-15.7 ± 5.8	-11.9 ± 5.7	0.089[a]
Frontal Trunk Lean	5.9 ± 4.2	1.8 ± 2.4	0.003[a]
Sagittal Pelvic Tilt	-8.2 ± 14.4	5.3 ± 7.0	0.007[a]
Frontal Pelvic Tilt	-6.9 ± 2.8	-5.5 ± 2.8	0.152
Trunk Flexion	-0.8 ± 8.6	-5.4 ± 10.0	0.186
Lateral Trunk Flexion	11.7 ± 4.3	6.6 ± 2.3	<0.001
	Three Months Post-operative		
Sagittal Trunk Lean	-15.9 ± 6.4	-11.9 ± 5.7	0.058[a]
Frontal Trunk Lean	5.3 ± 4.0	1.8 ± 2.4	0.002[a]
Sagittal Pelvic Tilt	-2.6 ± 13.8	5.3 ± 7.0	0.055[a]
Frontal Pelvic Tilt	-7.3 ± 3.8	-5.5 ± 2.8	0.073
Trunk Flexion	-3.6 ± 6.0	-5.4 ± 10.0	0.359[a]

Lateral Trunk Flexion	11.0 ± 4.7	6.6 ± 2.3	0.000[a]
	Six Months Post-operative		
Sagittal Trunk Lean	-15.4 ± 7.3	-11.9 ± 5.7	0.072
Frontal Trunk Lean	5.0 ± 5.4	1.8 ± 2.4	0.010
Sagittal Pelvic Tilt	-2.7 ± 16.3	5.3 ± 7.0	0.093[a]
Frontal Pelvic Tilt	-6.7 ± 2.0	-5.5 ± 2.8	0.110
Trunk Flexion	-0.6 ± 8.8	-5.4 ± 10.0	0.085
Lateral Trunk Flexion	9.8 ± 4.5	6.6 ±2.3	0.003
	One Year Post-operative		
Sagittal Trunk Lean	-14.5 ± 6.0	-11.9 ± 5.7	0.201[a]
Frontal Trunk Lean	2.8 ± 2.9	1.8 ± 2.4	0.217
Sagittal Pelvic Tilt	-3.6 ± 14.1	5.3 ± 7.0	0.030[a]
Frontal Pelvic Tilt	-5.7 ± 3.7	-5.5 ± 2.8	0.828
Trunk Flexion	-2.7 ± 7.7	-5.4 ± 10.0	0.327
Lateral Trunk Flexion	8.3 ± 3.2	6.6 ± 2.3	0.045

SD, standard deviation; TKA, total knee arthroplasty.
Sagittal trunk lean; (-) forward trunk lean.
Frontal trunk lean; (+) lateral trunk lean toward operated limb.
Sagittal pelvic tilt; (+) anterior tilt, (-) posterior tilt.
Frontal pelvic tilt; (-) downward tilt toward operated limb.
Trunk flexion; (-) forward trunk flexion, (+) trunk extension.
Lateral trunk flexion; (+) lateral trunk flexion toward operated limb.
[a] Indicates Mann-Whitney U was performed.

A greater frontal trunk lean was found in UKA patients pre-operatively (UKA = 7.0 degrees, CON = 1.3 degrees, p = 0.012) and at six weeks post-operatively (UKA = 8.6 degrees, CON = 1.3 degrees, p = 0.014) in comparison to controls. Unicompartmental knee arthroplasty patients in comparison to controls demonstrated less lateral trunk flexion at six weeks post-operatively (UKA = 12.6 degrees, CON = 6.3 degrees, p = 0.013), and a significantly greater sagittal pelvic tilt at six months post-operatively (UKA = -6.0 degrees, CON = 4.3 degrees, p = 0.024). The kinematic comparisons between UKA patients and controls can be found in Table 3.

Table 3.
Kinematic Comparisons Between UKA Patients and Controls

	UKA (N = 7, 9 knees) Mean ± SD	Control (N = 9, 9 knees) Mean ± SD	P Value
	Pre-operative		
Sagittal Trunk Lean	-15.3 ± 2.0	-13.0 ± 7.2	0.408[a]
Frontal Trunk Lean	7.0 ± 5.0	1.3 ± 2.8	0.012
Sagittal Pelvic Tilt	1.6 ± 12.2	4.3 ± 7.1	0.588
Frontal Pelvic Tilt	-5.2 ± 3.3	-5.7 ± 3.8	0.768
Trunk Flexion	-4.3 ± 5.1	-7.4 ± 12.1	0.408[a]
Lateral Trunk Flexion	10.9 ± 6.0	6.3 ± 2.8	0.210[a]
	Six Week Post-operative		
Sagittal Trunk Lean	-16.3 ± 6.6	-13.0 ± 7.2	0.319
Frontal Trunk Lean	8.6 ± 9.7	1.3 ± 2.8	0.014[a]
Sagittal Pelvic Tilt	-2.8 ± 13.7	4.3 ± 7.1	0.387[a]
Frontal Pelvic Tilt	-6.6 ± 3.9	-5.7 ± 3.8	0.629
Trunk Flexion	-5.7 ± 7.9	-7.4 ± 12.1	0.727
Lateral Trunk Flexion	12.6 ± 6.2	6.3 ± 2.8	0.013
	Three Months Post-operative		
Sagittal Trunk Lean	-13.04 ± 2.5	-13.0 ± 7.2	0.796[a]
Frontal Trunk Lean	3.1 ± 1.8	1.3 ± 2.8	0.126
Sagittal Pelvic Tilt	-3.8 ± 10.0	4.3 ± 7.1	0.222[a]
Frontal Pelvic Tilt	-5.7 ± 3.2	-5.7 ± 3.8	0.968
Trunk Flexion	-6.7 ± 3.8	-7.4 ± 12.1	0.796[a]
Lateral Trunk Flexion	8.9 ± 3.4	6.3 ± 2.8	0.102
	Six Months Post-operative		
Sagittal Trunk Lean	-13 ± 5.0	-13.0 ± 7.2	0.982
Frontal Trunk Lean	2.9 ± 1.7	1.3 ± 2.8	0.166
Sagittal Pelvic Tilt	-6.0 ± 10.1	4.3 ± 7.1	0.024
Frontal Pelvic Tilt	-4.6 ± 5.2	-5.7 ± 3.8	1.000[a]
Trunk Flexion	-9.1 ± 8.0	-7.4 ± 12.1	0.722
Lateral Trunk Flexion	7.8 ± 1.6	6.3 ± 2.8	0.193
	One Year Post-operative		
Sagittal Trunk Lean	-13.0 ± 2.6	-13.0 ± 7.2	0.743[a]
Frontal Trunk Lean	2.4 ± 1.9	1.3 ± 2.8	0.369
Sagittal Pelvic Tilt	0.2 ± 13.4	4.3 ± 7.1	0.606[a]
Frontal Pelvic Tilt	-4.6 ± 3.0	-5.7 ± 3.8	0.499
Trunk Flexion	0.6 ± 6.0	-7.4 ± 12.1	0.167[a]
Lateral Trunk Flexion	8.0 ±3.1	6.3 ± 2.8	0.270

SD, standard deviation; UKA, unicompartmental knee arthroplasty.
Sagittal trunk lean; (-) forward trunk lean.

Frontal trunk lean; (+) lateral trunk lean toward operated limb.
Sagittal pelvic tilt; (+) anterior tilt, (-) posterior tilt.
Frontal pelvic tilt; (-) downward tilt toward operated limb.
Trunk flexion; (-) forward trunk flexion, (+) trunk extension.
Lateral trunk flexion; (+) lateral trunk flexion toward operated limb.
[a] Indicates Mann-Whitney U was performed.

Total knee arthroplasty patients in comparison to UKA patients showed a significantly greater trunk flexion at six months post-operatively (TKA = -0.6 degrees, UKA = -9.1 degrees, p = 0.017). When comparing TKA to UKA, no other significant differences were found for any of the kinematic variables pre-operatively and post-operatively at six weeks, three months, six months, and one year. The kinematic comparisons between TKA and UKA patients can be found in Table 4.

Table 4.
Kinematic Comparisons Between TKA and UKA Patients

	TKA (N = 18, 24 knees) Mean ± SD	UKA (N = 7, 9 knees) Mean ± SD	P Value
Pre-operative			
Sagittal Trunk Lean	-17.4 ± 8.7	-15.3 ± 2.0	0.533[a]
Frontal Trunk Lean	7.1 ± 6.7	7.0 ± 5.0	0.956
Sagittal Pelvic Tilt	-2.5 ± 16.5	1.6 ± 12.1	0.549
Frontal Pelvic Tilt	-6.9 ± 3.7	-5.2 ± 3.3	0.302
Trunk Flexion	-2.5 ± 5.9	-4.3 ± 5.1	0.479
Lateral Trunk Flexion	11.6 ± 5.6	11.0 ± 6.0	0.790
Six Week Post-operative			
Sagittal Trunk Lean	-15.7 ± 5.8	-15.7 ± 6.8	0.702[a]
Frontal Trunk Lean	6.0 ± 4.2	8.6 ± 9.7	1.000[a]
Sagittal Pelvic Tilt	-8.2 ± 14.4	-2.8 ± 13.7	0.399
Frontal Pelvic Tilt	-7.0 ± 2.8	-6.6 ± 3.9	0.829
Trunk Flexion	-0.9 ± 8.6	-5.7 ± 7.9	0.205
Lateral Trunk Flexion	11.7 ± 4.3	12.64 ± 6.2	0.681
Three Months Post-operative			
Sagittal Trunk Lean	-15.9 ± 6.4	-13.0 ± 2.5	0.317[a]

Frontal Trunk Lean	5.3 ± 4.0	3.1 ± 1.8	0.183[a]
Sagittal Pelvic Tilt	-2.6 ± 13.8	-3.8 ± 10.0	0.660[a]
Frontal Pelvic Tilt	-7.3 ± 3.8	-5.7 ± 3.2	0.271
Trunk Flexion	-3.6 ± 6.0	-6.7 ± 3.8	0.174[a]
Lateral Trunk Flexion	11.0 ± 4.7	9.0 ± 3.4	0.236[a]
	Six Months Post-operative		
Sagittal Trunk Lean	-15.4 ± 7.3	-13.0 ± 5.0	0.370
Frontal Trunk Lean	5.0 ± 5.4	2.9 ± 1.7	0.272
Sagittal Pelvic Tilt	-2.7 ± 16.3	-6.0 ± 10.1	0.576
Frontal Pelvic Tilt	-6.7 ± 2.0	-4.6 ± 5.2	0.246[a]
Trunk Flexion	-0.6 ± 8.8	-9.1 ± 8.0	0.017
Lateral Trunk Flexion	9.8 ± 4.5	7.8 ± 1.6	0.210
	One Year Post-operative		
Sagittal Trunk Lean	-14.5 ± 6.0	-13.0 ± 2.6	0.940[a]
Frontal Trunk Lean	2.8 ± 2.9	2.4 ± 1.9	0.745
Sagittal Pelvic Tilt	-3.6 ± 14.1	0.2 ± 13.4	0.515
Frontal Pelvic Tilt	-5.7 ± 3.7	-4.6 ± 3.0	0.442
Trunk Flexion	-2.7 ± 7.7	0.1 ± 6.0	0.374
Lateral Trunk Flexion	8.3 ± 3.2	8.0 ± 3.1	0.832

SD, standard deviation; TKA, total knee arthroplasty, UKA, unicompartmental knee arthroplasty.
Sagittal trunk lean; (-) forward trunk.
Frontal trunk lean; (+) lateral trunk lean toward operated limb.
Sagittal pelvic tilt; (+) anterior tilt, (-) posterior tilt.
Frontal pelvic tilt; (-) downward tilt toward operated limb.
Trunk flexion; (-) forward trunk flexion, (+) trunk extension.
Lateral trunk flexion; (+) lateral trunk flexion toward operated limb.
[a] Indicates Mann-Whitney U was performed.

The knee extension strength of the operative limb was significantly less in TKA patients pre-operatively (TKA = 67.1 lbs., CON = 89.7 lbs., $p = 0.006$) and post-operatively at six weeks (TKA = 43.0 lbs., CON = 89.7 lbs., $p < 0.001$), three months (TKA = 54.5 lbs., CON = 89.7 lbs., $p < 0.001$), six months (TKA = 60.4 lbs., CON = 89.7 lbs., $p = 0.001$), and one year (TKA = 57.3 lbs., CON = 89.7 lbs., $p = 0.001$) in comparison to controls. Additionally, hip abduction strength was significantly less in TKA patients pre-operatively (TKA = 53.1 lbs., CON = 65.2 lbs., $p = 0.049$), and post-operatively at six weeks (TKA = 45.3 lbs., CON = 65.2 lbs., $p = 0.011$), three months (TKA = 48.4 lbs., CON = 65.2 lbs., p = 0.005), and at one year (TKA = 48.2 lbs., CON = 65.2 lbs., p = 0.017) in comparison to controls. The operative strength assessment between TKA patients to controls can be found in Table 5. The strength of the operative limb of UKA patients demonstrated no significant differences when compared to controls. The operative strength assessment between UKA patients to controls can be found in Table 6. Between the operative limb of TKA and UKA patients a significant difference was found in knee extension strength at six weeks post-operatively (TKA = 42.0 lbs., UKA = 66.5 lbs., p = 0.054). The operative strength assessment between TKA and UKA patients can be found in Table 7.

Table 5.
Operative Strength Assessment Between TKA Patients and Controls

	TKA (N = 18, 24 knees) Mean ± SD	Control (N = 25, 25 knees) Mean ± SD	P Value
	Pre-operative		
Knee Extension	67.1 lbs. ± 29.0	89.7 lbs. ± 25.6	0.006
Hip Abduction	53.1 lbs. ± 22.8	65.2 lbs. ± 19.0	0.049
	Six Weeks Post-operative		
Knee Extension	43.0 lbs. ± 29.8	89.7 lbs. ± 25.6	<0.001
Hip Abduction	45.3 lbs. ± 25.6	65.2 lbs. ± 19.0	0.011[a]
	Three Months Post-operative		
Knee Extension	54.5 lbs. ± 24.4	89.7 lbs. ± 25.6	<0.001
Hip Abduction	48.4 lbs. ± 21.2	65.2 lbs. ± 19.0	0.005
	Six Months Post-operative		
Knee Extension	60.4 lbs. ± 29.4	89. 7 lbs. ± 25.6	0.001
Hip Abduction	55.4 lbs. ± 25.6	65.2 lbs. ± 19.0	0.131
	One Year Post-operative		
Knee Extension	57.3 lbs. ± 35.9	89. 7 lbs. ± 25.6	0.001
Hip Abduction	48.2 lbs. ± 32.6	65.2 lbs. ± 19.0	0.017[a]

SD, standard deviation; TKA, total knee arthroplasty.
[a] Indicates Mann-Whitney U was performed.

Table 6.
Operative Strength Assessment Between UKA Patients and Controls

	UKA (N = 7, 9 knees) Mean ± SD	Control (N = 9, 9 knees) Mean ± SD	P Value
Pre-operative			
Knee Extension	81.9 lbs. ± 37.8	84.0 lbs. ± 24.6	0.888
Hip Abduction	62.6 lbs. ± 23.2	63.7 lbs. ±18.9	0.912
Six Weeks Post-operative			
Knee Extension	70.9 lbs. ± 26.9	84.0 lbs. ± 24.6	0.294
Hip Abduction	57.4 lbs. ± 15.5	63.7 lbs. ±18.9	0.452
Three Months Post-operative			
Knee Extension	67.7 lbs. ± 35.6	84.0 lbs. ± 24.6	0.275
Hip Abduction	52.7 lbs. ± 25.5	63.7 lbs. ±18.9	0.314
Six Months Post-operative			
Knee Extension	86.8 lbs. ± 38.0	84.0 lbs. ± 24.6	0.796[a]
Hip Abduction	62.7 lbs. ± 20.5	63.7 lbs. ±18.9	0.914
One Year Post-operative			
Knee Extension	90.0 lbs. ± 37.8	84.0 lbs. ± 24.6	0.699
Hip Abduction	64.0 lbs. ± 26.4	63.7 lbs. ±18.9	0.978

SD, standard deviation; UKA, unicompartmental knee arthroplasty.
[a] Indicates Mann-Whitney U was performed.

Table 7.
Operative Strength Assessment Between TKA and UKA Patients

	TKA (N = 18, 24 knees) Mean ± SD	UKA (N = 7, 9 knees) Mean ± SD	P Value
Pre-operative			
Knee Extension	64.2 ± 28.7	77.5 ± 37.5	0.350
Hip Abduction	50.3 ± 23.0	62.3 ± 23.0	0.277
Six Weeks Post-operative			
Knee Extension	42.0 ± 27.7	66.5 ± 25.8	0.054
Hip Abduction	45.1 ± 26.6	57.5 ± 17.8	0.270
Three Months Post-operative			
Knee Extension	55.5 ± 23.8	63.9 ± 37.2	0.507
Hip Abduction	49.8 ± 20.3	50.5 ± 28.8	0.942
Six Months Post-operative			
Knee Extension	56.7 ± 30.0	84.6 ± 39.9	0.086[a]

Hip Abduction	52.5 ± 25.3	62.9 ± 22.8	0.354
	One Year Post-operative		
Knee Extension	55.3 ± 35.6	87.5 ± 38.8	0.059
Hip Abduction	46.8 ± 30.8	60.9 ± 28.4	0.304

SD, standard deviation; TKA, total knee arthroplasty, UKA, unicompartmental knee arthroplasty.
[a] Indicates Mann-Whitney U was performed.

A significant difference in knee extension strength was found between the operative and non-operative limbs in unilateral TKA patients at six weeks (TKA = -23.9 lbs., p < 0.000) and three months post-operatively (TKA = -13.7 lbs., p = 0.002). The strength assessments of the operative and non-operative limbs of unilateral TKA patients can be found in Table 8. The strength assessment between the operative and non-operative limbs in UKA patients demonstrated a significant difference in knee extension at six weeks post-operatively (UKA = -14.8 lbs., p = 0.042). The strength assessments of the operative and non-operative limbs of unilateral UKA patients can be found in Table 9.

Table 8. TKA Operative and Non-operative Limb Strength Assessment

	Operative Limb (N = 12, 12 knees) Mean ± SD	Non-operative Limb (N = 12, 12 knees) Mean ± SD	T Value	P Value
	Pre-operative			
Knee Extension	61.0 lbs. ± 26.4	71.0 lbs. ± 22.0	-1.467	0.173
Hip Abduction	49.0 lbs. ± 21.0	50.3 lbs. ± 20.2	-0.586	0.571
	Six Weeks Post-operative			
Knee Extension	51.3 lbs. ± 18.0	75.1 lbs. ± 25.7	-6.160	<0.001
Hip Abduction	51.5 lbs. ± 20.7	50.7 lbs. ± 19.3	0.286	0.781
	Three Months Post-operative			
Knee Extension	60.4 lbs. ± 22.3	74.1 lbs. ± 26.3	-4.121	0.002
Hip Abduction	51.3 lbs. ± 16.8	52.2 lbs. ± 16.1	-0.583	0.571
	Six Months Post-operative			
Knee Extension	66.4 lbs. ± 26.6	68.7 lbs. ± 26.9	-0.457	0.658
Hip Abduction	57.7 lbs. ± 16.6	55.3 lbs. ± 25.2	0.670	0.522

	One Year Post-operative			
Knee Extension	66.4 lbs. ± 30.0	66.4 lbs. ± 28.3	-0.013	0.990
Hip Abduction	53.2 lbs. ± 20.5	54.0 lbs. ± 22.4	-0.270	0.793

SD, standard deviation; TKA, total knee arthroplasty.

Table 9.
UKA Operative and Non-operative Limb Strength Assessment

	Pre-operative			
	Operative Limb (N = 5, 5 knees) Mean ± SD	Non-operative Limb (N = 5, 5 knees) Mean ± SD	T Value	P Value
Knee Extension	73.1 lbs. ± 42.8	75.7 lbs. ± 33.0	-0.489	0.650
Hip Abduction	58.3 lbs. ± 31.2	56.1 lbs. ± 22.0	0.418	0.697
	Six Weeks Post-operative			
Knee Extension	77.0 lbs. ± 31.5	82.0 lbs. ± 22.0	-2.952	0.042
Hip Abduction	57.1 lbs. ± 21.7	56.2 lbs. ± 21.1	1.262	0.276
	Three Months Post-operative			
Knee Extension	58.2 lbs. ± 42.3	60.2 lbs. ± 37.5	-0.291	0.786
Hip Abduction	46.5 lbs. ± 34.0	41.8 lbs. ± 30.0	1.814	0.144
	Six Months Post-operative			
Knee Extension	81.0 lbs. ± 41.0	87.5 lbs. ± 28.2	-0.453	0.674
Hip Abduction	61.1 lbs. ± 27.1	58.0 lbs. ± 20.6	0.575	0.596
	One Year Post-operative			
Knee Extension	92.8 lbs. ± 45.8	86.0 lbs. ± 33.1	0.738	0.501
Hip Abduction	58.7 lbs. ± 34.2	58.1 lbs. ± 27.5	0.114	0.915

SD, standard deviation; UKA, unicompartmental knee arthroplasty.

DISCUSSION

The main finding of our study was that TKA and UKA patients demonstrated differences in sagittal and frontal plane trunk motion during stair descent when compared to healthy controls. Total knee arthroplasty patients demonstrated deficiencies in sagittal and frontal trunk lean, lateral trunk flexion, and a sagittal pelvic tilt in comparison to controls. Unicompartmental knee arthroplasty patients displayed deficits in frontal trunk lean, lateral trunk flexion, and a sagittal pelvic tilt in comparison to controls. At six months a significant difference in trunk flexion was found between TKA and UKA patients. The results of this study support the hypothesis that TKA patients exhibit increased sagittal and frontal plane trunk motion when compared to UKA patients and healthy controls. Total knee arthroplasty patients demonstrated a timeline of deficits pre-operatively to one-year and the deficits of UKA patients had a timeline of pre-operative to six months. This study is in line with previous studies in that the UKA procedure produces outcome measures that more closely resemble normal gait patterns and has a quicker recovery to functional levels than TKA [7, 14, 15, 17].

The limited research found on the kinematics of the trunk in healthy individuals indicate that trunk motion can influence the gait patterns of the lower extremity and is an important factor for posture, balance, and motor tasks [21-24]. In OA and TKA patients it is stated that compensatory changes in lateral trunk motion may affect the center of mass within the knee joint to reduce knee pain [2, 3]. Leardini et al [21] reported that variability in sagittal and frontal plane trunk motion can result in incorrect foot positioning and balance dysfunction which can increase the likelihood of falling. The findings of our research suggest that TKA and UKA patients are predisposed to balance dysfunction and falling.

The ability to effectively and safely descend stairs is a primary focus of this study due to the number of falls that occur in the elderly population and in the domestic setting [19, 25]. It has been previously reported almost fifty percent of adults with severe knee OA have experienced a fall within a year [1]. Stair descent, older age, increased trunk sway, balance impairment and muscle performance are considered predictors of falls [1, 18, 20, 25].

In addition to investigating the kinematics of the trunk during stair descent, we have compared the quadriceps and hip abductor strength in the operative and non-operative limbs of TKA and UKA patients. Quadriceps and hip abductor weakness is present in OA patients and persists following surgical intervention [1, 2, 4, 5, 8, 19, 26]. Studies have indicated that reduced quadriceps and hip abductor strength is associated with balance dysfunction and the ability to perform functional tasks [1, 2, 19]. It is previously reported that OA and TKA patients demonstrate a forward and lateral leaning of the trunk to compensate for reduced quadriceps strength [3-5, 24, 26]. These findings are supported in the present study. When compared to controls, the operative limb of TKA patients demonstrated significant differences in knee extension and hip abductor strength pre-operatively and post-operatively up to one year. The operative limb of UKA patients demonstrated no significant differences in knee extension or hip abductor strength when compared to controls. A significant difference in knee extension strength was shown at six weeks when comparing the operative limbs of TKA to UKA. Amongst the unilateral UKA patients a significant difference in knee extension strength was found between the operative and non-operative limbs at six weeks. In the unilateral TKA patients, significant differences were found in knee extension strength between the operative and non-operative limbs at six weeks and three months post-operatively. Our results are in line with previous research stating that reduced quadriceps strength is much less frequently found in UKA than TKA when compared to controls [7].

There are several limitations of this study that should be considered. The present study is part of a larger study and a variety of assistants performed strength assessments. The inter-rater reliability for strength assessments was not determined for our study. Second, participants were required to complete a health questionnaire and an activity assessment survey. Considering the deficits in strength assessment, future studies may consider implementing a rehabilitation questionnaire to better determine rehabilitation protocols given to TKA and UKA patients. Third, the patient exposure to stairs at home and in their occupation was not recorded. Determining stair exposure may influence a patient's ability to descend stairs. Lastly, a psychological factor in performing stairs should be considered. Osteoarthritis can lead to psychological changes causing patients to adopt coping strategies which can negatively affect their beliefs in performing tasks [1]. Several patients in the present study required an assistant to stand beside the stairs due to fear of falling.

CONCLUSION

Sagittal and frontal plane trunk motion are compensatory patterns seen in TKA and UKA patients while descending stairs. In TKA and UKA, hip abductor and quadriceps weakness is an important factor to consider in forward and lateral trunk lean and the ability to perform stair descent. Unicompartmental knee arthroplasty patients are able to return from trunk motion and strength deficits sooner than TKA patients.

REVIEW OF LITERATURE

Knee Osteoarthritis

Knee OA is a health issue world wide characterized for its severe pain and influence on gait kinematics [2, 3, 27]. Individuals with knee OA have reported knee pain, stiffness, and limited range of motion (ROM) [18]. Studies support that the debilitating symptoms of knee OA have resulted in restricted activities of daily living [18].

Tagliettia [1]. Postural balance is noted as a key factor that can be the cause of these functional limitations. Although in previous studies the cause of imbalance is unknown, studies have shown that reduced quadriceps function, diminished proprioception, and deterioration of knee balance can be strong factors in increased risks of falls. The purpose of this research article was to further investigate balance by determining whether the center of pressure (CoP) variables discriminate between OA and healthy controls and to determine if there is a correlation between CoP and Activities-Specific Balance Confidence Scale (ABC) and Falls Self-Efficacy Scale (FES). Lastly, to compare the CoP of OA elderly women and healthy controls. A total of 22 individuals were used for this research study. The Western Ontario and McMaster Universtities Osteoarthritis Index (WOMAC), Visial Analogue Scale (VAS), ABS, and FES were used for evaluations. A force platform was used for determining CoP. For statistical analysis the following tests were ran: Shapiro-Wilk Test, the Mann-Whitney Test, the Spearman Correlation Coefficient test, Wilks Lambda method, Box's M test, and SPSS Version 22.2. Results of this research study indicated that older women with OA had a greater postural sway with eyes open than healthy controls with eyes open. The correlations of CoP variables in discriminating between the two groups were not consistent and could not be correlated.

Research supports that OA patients have difficulty descending stairs and have a high prevalence of falls [1, 18]. Mobility impairment, muscle performance, and postural sway have been identified as factors that can contribute to the risks of falls [1]. Knee OA patients demonstrate quadriceps and hip abductor weakness leading to a reduced ROM in the knee and hip joints during stair descent [2, 18]. Proper rehabilitation and strict follow-ups can influence better outcomes [27].

Stair Descent

Patients with knee OA present with a decreased ability to perform stair climbing [26]. Stair climbing is a functional task commonly assessed in knee scoring tools after surgical intervention [8, 13]. Stair descent is considered one of the most difficult tasks perform and predisposes early to falling [18]. Knee OA patients have demonstrated a reduced quadriceps function, limited ROM, reduced walking speed, and diminished proprioception, all risk factors of falling down stairs [1, 18, 19, 25, 26, 28, 29].

Igawa [18]. The purpose of this study was to investigate the kinematics and kinetics of the lower extremity during stair descent in knee OA patients. To conduct this research a total of 12 subjects were recruited. There were eight control subjects between the ages 63 and 75. There were four subjects between the ages 69 and 83 in the experimental group. Results indicated that there were no significant differences between the two groups during stair descent. The knee and hip joint angle was smaller in knee osteoarthritis subjects than the healthy controls. There were significant differences in moments and power in ankle joint, knee and hips. This study only analyzed their variables in the sagittal plane.

Zeni [19]. The ability to use a set of stairs without assistance of a device or handrail is a growing concern. Researchers of this article hypothesized that preoperative measures of those who require handrail use and those who do not will predict whether handrail use would be used postoperatively. Knee flexion (ROM), quadriceps strength, and age are all variables that will be used to determine if their hypothesis is correct. A total of 169 subjects were chosen from a larger clinical trial. Results indicated that 63 of the 105 unilateral TKA subjects required handrail use during stair ascent and descent preoperatively. At three months, 65 subjects required handrail use. At two years, 60 of the subjects required handrail. Subject age was recognized as the best predictor for handrail use. It was determined that BMI, knee flexion (ROM), and surveys were not recognized as strong determinants for handrail use. It was found that those who required handrail use took a longer amount of time to complete stairs, had weaker quadriceps strength, and had less knee extension. The results for this study does support the hypothesis of the researchers.

Jung [13]. The purpose of this study is to compare knee kinematics and kinetics of simultaneous total knee arthroplasty (TKA) and unicompartmental knee arthroplasty (UKA) patients during stair walking. Four females two males with a TKA in one knee and a UKA in the other knee were included in this study. One surgeon used either the Oxford meniscal-bearing unicompartment replacement system prosthesis (Biomet, Warsaw, IN, USA) for UKA or the Legacy LPS- Flex fixed bearing knee prosthesis (Zimmer, Warsaw, IN, USA) for TKA. Participants underwent a biomechanical analysis of five roundtrip stair walking. For statistical analysis the SAS software was used (9.1, SAS, Institude Inc.) along with the Friedman test to compare results. Results indicated that UKA and TKA demonstrated similar knee kinematics in the coronal and sagittal planes during stair descent. Unicompartmental knee athroplasty allowed for greater degree of rotation in the transverse plane, closely resembling normal knee kinematics. No significant differences were found in the ground reaction forces (GRF), knee joint reaction force, and joint moment in all planes in both TKA and UKA knees. Between stair ascent and descent, stair descent demonstrated greater parameters; greater knee angles in all three planes, vertical GRF, joint reaction force, and moment.

Almeida [30]. Testing total knee arthroplasty subjects on the use of stair performance has served as a common way to determine their functional ability and limitations. The purpose of this study was to determine the inter-rater reliability and measurement error of stair ascent and descent, determine whether there is a correlation between stair ascent and descent measures to physical function, and measures relative to lower extremity muscle weakness and ROM in TKA subjects. A total of 43 eligible subjects were used. Results indicated that the intra-class correlation coefficient (ICC) represented good reliability. The stair ascent and descent plot indicated system bias whereas the stair ascent alone indicated no system bias. Results also found a correlation between performance-based tasks to the stairs test. Subjects who took longer to perform their performance function tasks were generally slower at the stairs test versus those who performed their functional task at a quicker pace and completed the stairs at a faster rate. It was determined that those with greater muscle strength completed the stairs quicker. There was no correlation to knee extension on the ability to complete the stairs. Knee flexion was found to be correlated with stair use; subjects who showed limited flexion took longer to complete the stair task.

Vallabhajosula [31]. Ascending stairs is a challenging activity of daily living for many populations. Frontal plane joint dynamics are critical to understand the mechanisms involved in stair ascension as they contribute to both propulsion and medio-lateral stability.

However, previous research is limited to understanding these dynamics while initiating stair ascent from a stand. We investigated if initiating stair ascent from a walk with a comfortable self-selected speed could affect the frontal plane lower-extremity joint moments and powers as compared to initiating stair ascent from a stand and if this difference would exist at consecutive ipsilateral steps on the stairs. Kinematics data using a 3-D motion capture system and kinetics data using two force platforms on the first and third stair treads were recorded simultaneously as ten healthy young adults ascended a custom-built staircase. Data were collected from two starting conditions of stair ascent, from a walk (speed: 1.42 +/- 0.21 m/s) and from a stand. Results showed that subjects generated greater peak knee abductor moment and greater peak hip abductor moment when initiating stair ascent from a walk. Greater peak joint moments and powers at all joints were also seen while ascending the second ipsilateral step. Particularly, greater peak hip abductor moment was needed to avoid contact of the contralateral limb with the intermediate step by counteracting the pelvic drop on the contralateral side. This could be important for therapists using stair climbing as a testing/training tool to evaluate hip strength in individuals with documented frontal plane abnormalities (i.e. knee and hip osteoarthritis, ACL injury).

Verghese [25]. One-third of adults 65 years of age and older living in community-residing homes represent fall each year. Despite the clinical risk assessments of falls and fall intervention trials, the high rates of falls require a better understanding of fall risk factors. Verghese et al., conducted this study to determine whether and to what extent gait speed and other gait markers are independently associated with risk of falls in a cohort of community-residing adults aged 70 and older. Participants performed a gait analysis using a computerized walkway with embedded pressure sensors. Of 597 eligible participants, 115 fell once and 111 had recurrent falls. Older age, slower walking speed, gait abnormalities, and disability scores were found to be associated with an increase risk of falling.

In comparison to healthy individuals, smaller knee and hip joint ROM can be found in knee OA patients while descending stairs [18]. Research indicates that TKA patients with muscle weakness descend stairs at a slower pace and require handrail use [19, 30]. Both TKA and UKA provide similar knee kinematics during stair descent with the exception of greater knee rotation in UKA patients [13].

Trunk Kinematics

Recent studies support the role of the trunk as an important contributor of posture, balance, and dynamic stability [21, 23, 24]. Slow gait velocity, muscle performance, and insufficient trunk stability are associated with a higher risk of falling [1, 20, 21]. In walking gait and stair climbing, knee OA and TKA patients demonstrate increases in sagittal and frontal plane trunk motion as compensatory strategies for pain and reduced quadriceps strength [3-5, 22].

Der, van, [3]. Lateral trunk rotation has the potential of changing the body's center of mass relative to the knee. Researchers hypothesized that a higher level of knee pain is associated with higher lateral trunk motion in patients with knee OA. A total of 63 subjects were recruited. To determine if the hypothesis was correct, the researchers used data from six walking trials, timed 100 meters walking, and muscle strength isokinetic testing. The hypothesis that a higher level of knee pain is associated with higher lateral trunk motion in patients with knee OA was not proven. In bivariate analyses, results indicated that lateral trunk motion did not show a correlation to knee pain in the VAS. In WOMAC lateral trunk movement was not found to be correlated either. Researchers did find a positive correlation in WOMAC and knee stiffness. Researchers also found that pain between VAS and WOMAC were correlated. Researchers did find a positive correlation in the regression analyses between VAS knee pain and lateral trunk movement. Although a positive correlation was found, it was found considering other variables such as age, gender, stiffness, and walking speed. Researchers concluded that younger female patients with a higher rated knee stiffness and higher walking speed had greater lateral trunk movements. WOMAC showed no correlations in regression analysis.

Leardini [21]. The purpose of this study was to determine thorax inclinations in the sagittal plane on pelvis and upper trunk segment kinematics during walking gait. Researchers were also interested in determining which inter-segmental motions and anatomical axis rotations were affected the most and if gender played a role in these factors. Results were analyzed in spatio-temporal parameters, patterns of rotation, Nested analysis of variance (ANOVA) for a-segments, Nested ANOVA for b-axes, and Nested ANOVA for c-Periods. Subjects were divided into backward (BW) inclination or forward (FW) inclination. In spatio-temporal parameters, subjects demonstrated small differences between the two groups. In the patterns of rotation comparison, the two groups showed consistent thorax inclination during distinct period of the walking gait. In ANOVA for a-segments, the BW inclination group showed motion at the shoulder and thorax and thorax and laboratory but less at the thorax and pelvis. The motion magnitude for b-axes showed the BW with smaller numbers. In c-period, the BW group showed a significantly smaller number at push-off.

Crosbie [32]. The purpose of this study is to compare patterns and ROM of spinal segments in young and old female and male groups during self-selected speed walking gait. To analyze spinal movement, this research divided the spine into lower thoracic, lumbar, and pelvic segments. A total of 108 were recruited with 50 males and 58 females between the ages 20 and 82. Results showed that senior females appeared to walk significantly slower than the junior females and males. Senior females were found to have walked the slowest of all groups while junior males were the fastest of all groups. Step length showed differences between ages but not genders. For the motion of lateral flexion there were no significant differences between genders and age. For spine flexion and extension, a faster speed showed less coefficient of variance during fast speed walking. Females of both groups demonstrated a difference in spinal pattern in comparison to men. Junior female had a wider ROM in the pelvic segment in comparison to all other groups. Senior males showed the lowest ROM in the pelvic segment for flexion and extension. There were no significant differences in axial rotation between any of the groups in any of the spinal segments. Range of motion between spinal segment different greatly at both speeds between both groups and ages. Seniors are assumed to have reduced motion due to age. Fast speed in women showed greater motions at all spinal segments. Males only showed a change with increased speed in lateral flexion. In summary, the results of this research study does show support to the hypothesis. Speed, gender, and age all showed influence on spinal movement.

Crosbie [32]. This research study is connected and part of the previous study. Instead of looking at gender, speed, and age on trunk segment motions, this research article focuses on three planes motions of three spinal segments only during self-selected free-speed walking. The three planes of motions that were investigated were flexion and extension, lateral flexion, and axial rotation. The planes of motions that were studied were at the lower thoracic, lumbar, and pelvic regions. The range of age was between 20 and 82. Although numbers of ROM between the spinal segments were small, the numbers were significant enough to support the hypothesis of this research study. The lumber segment of the spine showed the greatest peak-to-peak ROM in lateral flexion. Lateral flexion showed the greatest ROM in comparison to other motions of plane in all segments. Flexion and extension of the spinal segments followed a pattern. The lower thoracic segment showed significantly less flexion and extension than the other segments. Axial rotation throughout the entire spine was limited. No significant differences between the three segments in axial rotation were noted.

Kavanagh [33]. Research has been conducted on how velocity affects lower body movement. There has been limited research on how velocity affects upper body motion. The purpose of this research article was to investigate the influence of gait speeds on lower trunk motions. Trunk accelerations were analyzed by determining anterior-posterior (AP), mediolateral (ML) and vertical (VT) directions. These accelerations were not used for variability in body segment motions. Rather, they were used in a matter of comparison to spatial and temporal variability. Trials included different speeds: slow selected pace, preferred pace, and fast pace. There were a total of 13 subjects within the ages 23 and 26. The difference in walking speeds were found to alter trunk amplitude. Furthermore, it was found that ML and VT in slow selected speed had less regularity and repeatability than compared to preferred walking speeds. Although there were statistical differences between slow and preferred walking speeds, there were no differences between preferred and fast walking speeds. For this it is suggested that the body might reserve its trunk motion at faster speeds due to balance comfort level. It was also stated that accelerations in ML and VT shifted to assist in controlling trunk motions during faster paced walks.

Lee [20]. The purpose of the conducted research in this article was to determine quantitative norms of trunk sway in elderly people while also determining the dynamic sway in normal and abnormal gaits of elderly (normal trunk sway and trunk variance throughout walking). In previous studies, trunk sway of elderly people has been compared to younger people or other populations. There are no previous studies on what normal values are in elderly people. Trunk sway should be determined with consideration of both gait velocity and abnormal gait. Researchers found that roll angle increased with velocity in normal gait subjects while those of abnormal gait they could not make correlations. To determine trunk sway normal values and trunk sway with consideration to velocity in abnormal gait, subjects underwent walking trials at a preferred pace. Two hundred and eighty-four subjects of the age 65 were recruited from a previous longitudinal research study. A body mounted gyroscope, Sway Star (Balance International Innovations GMBH, Switzerland), was used to determine trunk sway. Results indicated that women demonstrated greater trunk sway than men in both planes. There were no significant differences in angle velocity or roll in either planes for both genders. Pitch angles were the highest in the oldest men. Men showed no differences in roll or pitch velocity in any age. Women showed decreases in roll with increasing age. Women showed no difference in pitch.

Ceccato [22]. The purpose of this research study was to determine the role of the erector spinae (ES) in driving the trunk and lifting the leg during normal walking. The other purpose was to investigate how the trunk contributes to the transition from postural to dynamic states. The subjects underwent walking trials at self –selected speeds on pathways that consisted of force plates. Along with markers that were placed on the subject for kinematics, the subject also wore surface electrodes to record ES activity during walking. Nine men were recruited for this study. The men were between the ages 23 and 42. Electromyography (EMG) recordings of ES analyzed peaks of one gait initiation and one walking cycle of each subject. Kinematic results were analyzed by sagittal, frontal, and horizontal planes. In the sagittal plane, the gait initiation phase showed an increase in lordosis that decreased during the walking cycle. In the frontal plane, an increase in lateral flexion occurred towards the stance leg during every swing phase. The initiation of lateral flexion occurred in top-down with the ES activation occurring in descending pattern on the same side. In the horizontal plane, there was a rotation in the thoracic region towards the swing leg (similar pattern that is found in frontal plane). Results of the research study demonstrated increases in ES activation during gait initiation and walking by analyzing all three planes of movement.

Krebs [24]. There is little to no research on the upper body kinematics during walking gait, stair ascent and descent, and rising from a chair. The purpose of this research study is to gear the focus to upper body kinematics. More specifically, trunk ROM and angular peaks, and kinematics of trunk in relation to room and trunk in relation to pelvis. Eleven subjects were chosen. Researchers analyzed kinematics of all activities by planes: sagittal, transverse, and frontal. The trunk ROM relative to room and pelvis showed significant differences in the rising from a chair activity than gait and stairs. The greatest ROM of trunk in relation to pelvis was seen with the rising from a chair. No statistical differences in sagittal or transverse planes for rising from a chair were shown. Walking gait showed similar results to descending stairs in all planes but differed in ascending. No significant differences were found between ascending and descending with the exception of medial and lateral rotations. In the walking gait no significant differences were shown between trunk in relation to room and trunk in relation to pelvis. The stairs showed significant differences between trunk in relation to room than trunk in relation to pelvis (ascending in particular).

Chung [23]. Research was conducted to identify the kinematics of normal trunk motion by using three dimensional gait analysis to determine if there were significant differences between the trunk motion of men and women. Results were analyzed for normal values of trunk motion comparison between trunk motion in pelvic and global references, comparison between men and women, and correlations between motion planes in trunk motion. Ranges of motion in global reference frame were smaller than that of the pelvic reference frame. Range of pelvic rotation was greatest and range of pelvic tilt was smallest in the pelvic reference frame. Ground ROM was the largest and ground range of obliquity was the smallest in the global reference frame. The mean tilts in both ground and pelvic reference frames were less in women than in men. Results suggested that women displayed a larger coronal motion in the pelvis segment than males. Researchers also found that trunk motion in the coronal plane was correlated to trunk motion in the transverse plane.

Asay [26]. Stair climbing ability is frequently used as a measure of function. Research has demonstrated that loss of quadriceps function is directly related to the ability to ascend stairs. Furthermore, research suggests that knee OA patients lean their trunk forward to compensate for quadriceps weakness. The purpose of this study was to determine if patients with knee OA of varying severity adopt an altered pattern of movement to reduce the net quadriceps demand by learning their trunk forward while ascending stairs. Recruited subjects performed three stair-ascending trials on each leg at a self-selected speed. Statistical analysis using ANOVA revealed differences in peak knee flexion moment and trunk flexion angle between less, more severe patients, and control subjects. Correlations were found between trunk flexion angle and knee flexion moment for less and more severe patients using a linear regression model. Patients with severe OA demonstrated greater peak trunk flexion angles and hip flexion in comparison to controls. Patients with more severe OA that demonstrated greater peak trunk flexion angles also demonstrated lower peak knee flexion moments.

Trunk kinematics is found to be associated with age, gender, walking speed, stiffness, and dynamic stability in elderly individuals [3, 21]. Walking speeds have shown to alter trunk motion [33]. Elderly women walk significantly slower and demonstrate greater sagittal and frontal plane trunk motions in comparison to age-matched men [20]. Furthermore, elderly people have shown a tendency to learn their trunks forward during gait to maintain dynamic stability and reduce the risk of falling [21].

Muscle Weakness

Quadriceps, hamstring, and hip abductor weakness is often present in knee arthroplasty patients [2, 5]. As a result of limited knee-joint motion, TKA patients develop a quadriceps avoidance and compensate with trunk flexion [4, 5]. Research indicates that quadriceps and hip abductor strength are highly related to a patient's ability to perform functional activities [2, 19] . Muscle weakness and a reduced gait velocity increase the difficulty of climbing stairs and the risk of falls [1, 5, 19, 33].

Schache [2]. Research focuses on the postoperative functional limitations and possible improvements in physical rehabilitation. Prior to surgery patients with end-stage knee OA demonstrated weak hip abductors and compensatory gait patterns. The purpose of this research was to provide a comparison in hip abductor strengthening to the traditional TKA rehabilitation to determine if there is a positive correlation in the additional hip strengthening exercises to the patient oriented and functional outcome measures. A sample of 104 females and males over the age of 50 were measured at three-weeks, six-weeks, and six-months. Results have yet to be determined.

Bjerke [5]. Post-surgically TKA subjects have indicated a decreased ability to climb stairs along with weakness in the quadriceps and hamstrings. Previous research has concluded that TKA subjects demonstrate an increase in trunk flexion during stair ascent that causes a decrease in knee flexion leading to an increase in quadriceps muscle weakness. The hypothesis of this article was that during stair ascent TKA uses more of their quadriceps and hamstrings muscular capacity with an increase in forward trunk lean than healthy controls. A cross-sectional study, subjects were chosen based on their post-surgical timeline between one to three years. Twenty-three met the inclusion criteria of less than 65 years of age to avoid age related limitations. Results demonstrated that there were no differences between TKA and controls in forward trunk lean.

Li, Katherine [4]. It is commonly found that post-surgical gait aberrations in TKA patients involve a reduced knee extension moment and limited knee and hip flexion. With a three-dimensional gait analysis, researchers aim to understand lower extremity muscle function on its ability to accelerate the body's center-of-mass. Research focused on the muscle function of the back, hip, knee, and ankle variety between healthy controls and TKA's. The age bracket of subjects was between 67 and 74. The timeline for this study was from data over 12 months post-surgical. Due to the data collected being retrospective, subjects and research tools were used from a previous study. Results indicated that TKA subjects had smaller knee and hip flexion angles in the early stance, increased back flexion during the terminal phase of stance, increased plantarflexion, and net back extension being greater during entire gait.

Hip abductor and quadriceps weakness are present pre-operatively and persist post-operatively [2]. Hip abductor weakness is often ignored in post-operative rehabilitation programs [2]. Hip abductors and quadriceps contribute to the ability of rising from a chair, turning while walking, and stair climbing [2]. By improving muscle strength preoperatively and post-operatively, it is likely that functional outcomes will improve [2].

Total Knee Arthroplasty

Total knee arthroplasty is a widely accepted knee intervention for moderate to severe knee OA [4, 9]. With the prevalence of arthritic disease in the aging population, it is estimated that TKA procedures will increase to three point five million by 2030 [4]. Total knee arthroplasty is recognized as the most effective operative treatment for knee OA due to patient reported outcomes (PROM) of improvements in pain, functional performance, and durability [2, 4, 6, 9, 12, 19].

Stan [28]. The purpose of this article was to determine the changes in human gait and postural control in preoperative and postoperative unilateral TKA patients. Several tests were used to determine the changing variables of free moment and displacement. Walking trials were used to determine free moment (torsional loading) and orthostatic testing with eyes open and eyes shut were used for displacement. The tests were given to subjects two days prior to surgery and 12 days after total knee replacement (TKR). The study group consisted of ten subjects with a mean age of sixty-three. Postoperatively TKA subjects had an increase in torsional loading in comparison to the control group. The study also showed significant increased in anteroposterior displacement in postural control with both eyes open and shut.

Standifird [8]. The purpose of this article is to compare lower- limb biomechanics to replaced and non-replace TKA subjects to healthy control limbs during stair ascent. Researchers also hypothesize that in the sagittal plane of the knee, there would be similar function in the replaced and non-replaced knees but different to a control knee. It is also hypothesized that frontal plane of the replaced and non-replaced knees would be different but the same between the replaced knee and control limb. A total of 13 TKA subjects and 15 control subjects were matched by age and recruited. Results indicated that the controls had greater ROM and greater knee flexion at contact. The knee extension of the control and non-replaced limb were greater than the replaced limb. Push-off peak abduction in the control limb was smaller than the replaced and non-replaced knees. The hip of the replaced knee had greater flexion at contact than the non-replaced. Hip peak abduction was smaller in the control limb than the replaced limb.

Christiansen [34]. The purpose of this article and research was to address weight bearing (WB) differences in postoperative TKA patients to control subjects, the examination of lower limb movement symmetry by sit-to-stand, and lower limb functional performance after WB training. Twenty-six patients were chosen between the ages 67 and 75 with knee OA and whom were to undergo unilateral TKA. Data was collected at one-two weeks preoperatively, six-weeks postoperatively (at the end of intervention), and twenty-six postoperatively for long-term. Intervention included standard care of rehabilitation by itself (control group) and standard care of rehabilitation plus weight bearing biofeedback training (RELOAD group). The WB ratio was used during walking trials and Five Time Sit-to-Stand Test (FTSST). Results indicated that there were no differences in WB in sit-to-stand or in walking speed at six weeks. The RELOAD group had a greater reduction in time to perform the test and at twenty-six weeks the RELOAD group tended to walk at faster speeds.

Verra [9]. The purpose of this study is to evaluate how factors influence the opinion of surgeons on the decision to recommend TKA surgery. Researchers hypothesized that the Dutch Orthopaedic Surgeons would recommend TKA to patients with a high-grade radiological OA, high levels of pain, and older age. Access to a computer was the primary resource for the conduction of this study. A total of 326 surgeons were participated in the study. A Chi-squared test, five-point Likert scale, and SPSS for Windows, version 20 was also used for testing and statistical analysis. Results indicated that surgeons were more willing to perform a TKA on an older patient, no differences were shown on the decision to perform TKA between mild and severe pain, and surgeons were less likely to perform TKA on patients with mild radiological OA compared to those with severe. Activities of daily living, low quality of life, severe pain, limited walking distance, along with other factors were positively associated to the decision making process.

Mahoney [35]. Researchers have determined that the extension mechanism, anterior knee pain, and crepitus, post surgically, can be due to the prosthetic design of the implants being used. It is stated that implants with multi-radius profiles do not fully restore the extension mechanism of patients. It is hypothesized that a single radius implant with a more posterior flexion-extension axis, would improve the extension function. One surgeon performed the TKA. One hundred knees were replaced with a multi radius implant titled Series 7000 PPSK (OSteonics, Allendale, NJ). Another 100 knees were replaced with a single radius implant titled Scorpio (Osteonics, Allendale, NJ). The rising from a chair test was the primary test used for determining knee extension, knee pain, and knee crepitus. Results were broken down by functional scores, degrees of knee flexion, and chair rising. Functional scores between the two implants showed no significant differences. There were no significant differences between the two implants in knee flexion, with the exception of a large gap at six-weeks where single radius showed a higher degree of flexion. There were no significant differences between the two implants with rising from a chair. Although there were no significant differences, single radius showed a more rapid increase. With rising from a chair, the single radius implant also showed less results of anterior knee pain, and pain diminished quicker than the multi radius implant.

Stoddard [36]. Researchers investigate the mid-range stability of multi radius implants to single radius implants, and both implants to an intact knee. Researchers hypothesize that with the newer single radius implant design, there will be less instability in the mid-range of gait. To compare single and multi radius implants to each other and to the intact knee, frozen lower limbs were used. Mid-incisions in the prepatellar region the implant of both single and multi radius were used. To determine mid-range instability of multi and single radius implants to an intact knee, anterior-posterior, internal-external rotation, varus-valgus laxity translations were investigated. After careful procedures and analysis, researchers concluded that there were no significant differences between either TKA implants. They could not support their hypothesis that single-radius TKA implants would cause less midrange instability or that multi-radius implants induce instability. Although no significant differences were shown, anterior-posterior translations of both TKA implants showed significant differences to the intact knee. In internal-external translations, internal rotation of both the implants match that of the intact knee. In the varus-valgus translation, both implants matched the intact knee as well.

Pethes [27]. The purpose of this research article was to determine the variability of gait patterns between two different TKA surgical techniques to a control group in the early postoperatively stages. The two patient groups were divided by two different surgical techniques; Group II underwent an invasive technique by an incision at the median parapatellar area and Group III underwent a surgical technique that was minimally invasive by using a quadspring midvastus incision. Total knee arthroplasty subjects were between the ages70 and 76. A rigid PosturoMed plate was used for motional analysis of stepping cycles. Measurements were taken up to 12 weeks postoperatively for TKA subjects. Measurements of the knee and trunk were measured separately. The results indicated that the least invasive surgical method (Group III) researched closer to normalization values at a quicker pace than Group II.

Walsh [29]. Total knee arthroplasty is often the surgical treatment for individuals with sever knee OA. With the need to document persistent physical impairments and functional limitations in patients with knee OA, the purpose of this study was to examine knee ROM, muscle torque, total work, and functional limitations such as walking and stair climbing. Participants one year after TKA surgery were included in this study. Total knee arthroplasty patients demonstrated greater mean peak torque of the knee extensors in comparison to knee flexors. When comparing total work, deficits were found in knee extensor and flexor concentric peak torque. Individuals with TKA achieved 80% of normal walking speed in comparison to age- and gender-matchers participants. Women and men with TKA took twice as long ascending and descending stairs.

Despite improvements in pain, functional activities, and implant survivorship, 17-25% of patients report dissatisfaction and a decreased ability to perform basic functional tasks [5, 8, 9, 36]. Years following surgery, TKA patients demonstrate muscle weakness, knee pain, and an abnormal gait pattern [3, 5, 26, 27]. The effectiveness of TKA is highly dependent on patient selection, the timing of operation, the rehabilitation program, and strict follow- ups [9, 27, 28].

Unicompartmental Knee Arthroplasty

Twenty percent of patients with knee OA have isolated unicompartmental OA [10, 12]. Unicompartmental knee arthroplasty is an alternative procedure for knee OA limited to one compartment [10] [6]. Unlike TKA, UKA is a minimally invasive approach that preserves bone stock and both cruciate ligaments [7, 12, 13, 15]. In comparison to TKA patients, UKA patients have shorter hospitalization stays, shorter rehabilitation, ability to ambulate independently sooner, and improved functional scores [11-15, 17]. Studies support that UKA patients exhibit a more normal walking gait and stair climbing ability in comparison to TKA patients [6, 7, 10, 13, 16, 17].

Ollivier [11]. Lateral UKA is considered to be more challenging than a medial UKA due to the functional anatomy of the lateral compartment. The goal of this research is to provide indications, pre-operative preparation, surgical technique, and results for lateral unicompartmental UKA. Researchers concluded that painful OA, osteonecrosis (OCN), or post-traumatic arthritis limited to the lateral compartment of the knee associated with a loss of joint space are indications for lateral UKA. Patients are prepared pre-operatively physically and psychologically by maintaining ROM and strength and presenting post-operative goals of rehabilitation early on. The following techniques must be considered when performing lateral UKA: undercorrection of deformity, the divergence of the lateral femoral condyle to avoid impingement, excessive lateral placement avoidance in extension to prevent overload of the lateral compartment during flexion, and internal rotation in the sagittal tibial cut for the "screw-home" mechanism. The Knee Society pain and function scores of lateral UKA improved significantly between pre-operative and post-operative evaluations. Patients demonstrated an improved active knee flexion ROM. Sixty-two point three percent of patients were enthusiastic of the procedure. Researchers concluded that lateral UKA can provide reasonable results with a survivorship similar to medial UKA.

Jones [7]. Researchers have hypothesized that due to the joint preserving technique in UKA surgical intervention, healthy controls will closely resemble UKAs than TKAs. Out of one hundred and forty-five participants, 121 were healthy controls, 12 were TKA, and 12 were UKA subjects. TKA and UKA subjects were matched according to age, height, and body mass index (BMI). Subjects were to have undergone a total of twelve months of rehabilitation post-surgery.

A treadmill that was instrumented with force plates was use for gait analysis. A Zimmer Biomet implant from Bridgend, United Kingdon, was used for UKA implants. The Gensis II cruciate-retaining TKA by Smith & Nephew from Longdon, United Kingdom, were used for TKA implants. The Oxford Knee Scores (OKS) was used during the time of gait analysis. Matlab was used for programming. With the use of a decision tree used to determine outputs, 111 (92%) of healthy controls were classified as resembling UKA subjects. Only six (five percent) of TKA were classified as closely resembling UKAs. The peak walking speed of TKA was much lower than UKA and healthy controls. The peak walking speed of UKAs and healthy controls closely resembled each other.

Yang [12]. Recent research has indicated that the survivorship of UKA is close to that of TKA. The purpose of this research study was to perform a matched-pair comparison b/w the minimally invasive UKA and traditional TKA for patients with isolated medial compartmental OA of the knee to confirm its early advantages. The mean age for the UKA group was 65.1 and the mean age group for TKA was 65.5. The UKA group consisted of eight males and 42 females. The TKA group consisted of six males and 44 females. Both groups had similar characteristics. For the UKA procedure two types of implants were used: Miller-Galante Unicompartmental (Zimmer, Warsaw, IN) and P.F.C. Unicompartmental (Depuy, Leeds, UK) knee systems. Both implants involved minimally invasive techniques. Parameters were compared using a t-test. Subjects in both groups followed a TKA rehabilitation and were followed-up at six-months post surgery. Results indicated that UKA subjects had a quicker rehabilitation and ability to ambulate independently earlier at an average of two point one post-operatively in comparison to five point four for TKA post-operatively. UKA achieved a flexion of 90 degrees after three point six days in comparison to TKA at six point nine. UKA had a hospitalization of five point nine days in comparison to TKA at nine point four days. At six-months patients with UKA had a greater ROM of 122 degrees in comparison to TKA that had 108.

Horikawa [6]. There are few studies that have compared the long-term outcomes of TKA and UKA. Therefore, the purpose of this study is to compare the results of TKA and UKA preoperatively and postoperatively. Forty-eight subjects had fifty primary TKAs and 25 subjects had 28 UKAs performed. Clinical data was recorded preoperatively and post-operatively at two-weeks, one-month, three-months, six-months, one year, and the most recent follow-up. Femoro-tibial angle (FTA), ROM, Japanese Orthopedic Association (JOA) scores, and Japanese Knee Osteoarthritis Measure (JKOM) were recorded for clinical analysis. The Stryker Scorpio implant was used for TKA procedures (NRG, Japan Stryker Company, Tokyo, Japan) and the fixed-bearing Stryker was used for UKA procedures (Stryker EIUS UKA). A chi-square test, non-matched pair analysis for two group comparisons, Mann-Whitney U Test, Kaplan- Meir Survival Analysis, Microsoft Office Excel and Statcel 3 (OMS, Inc., Tokyo, Japan) were used for assessments and comparisons. In comparison to TKA, UKA showed higher FTA and ROM numbers preoperatively and post-operatively. This research study confirmed that UKA had higher postoperative outcomes measures (FTA and ROM) and the survivorship rates in implants were greater in TKA than in UKA.

Fu [10]. Currently, there is limited research on the external knee kinematics for UKA, more specifically, the biomechanics between lateral UKA compared to medial UKA. The purpose of this study is to determine if groups of patients with medial UKA or lateral UKA with a non-diseased contralateral limb would display inter-limb symmetry during stair ascent, to evaluate the variation between inter-limb kinematics between participants, and to report stair kinematics performed by both UKA groups. A total of 26 healthy patients with either medial

UKA or lateral UKA and a non-diseased contralateral limb were recruited for this study. Surgery was performed by one surgeon that used either an iBalance Unicondylar Knee (Arthrex, Naples, FL, USA) or a Zimmer Unicompartmental High Flex Knee System (Zimmer, Warsaw, IN, USA) implant. A biomechanical analysis was performed during stair ascent. The ground reaction forces (GRF) were filtered using a fourth-order Butterworth low-pass filter at 100hz cutoff frequency. A paired t-test was used to determine clinically significant differences. Data analysis was performed using the MATLAB 7.0 (Mathworks, Inc, Natick, MA, USA). Results indicated that the average outcomes for temporal and kinematic variables of the UKA groups showed no clinical significant inter-limb differences. Individual participants within each UKA group displaced significant inter-limb differences.

Lastad [15]. When considering UKA, it is suggested to compare the short-term results to the long-term risk of revision rate. The aim of this study is to compare pain and function of unrevised UKA and TKA at a minimum of two years following surgery. One thousand three hundred and forty-four patients 85 of age or younger were included in this study. Three brands of implants for UKA were included in this study: Genesis Uni (Smith & Nephew, Memphis, Tennessee), Miller-Galante all polyethylene tibial Uni (Zimmer, Warsaw, Indiana), and Oxford III (Biomet, Bridgend, South Wales, United Kingdom). The implant brands for TKA participants included AGC (Biomet), Genesis I (Smith & Nephew, LCS (DePuy, Leeds, United Kingdom), and NexGen (Zimmer). The Knee Injury and Osteoarthritis Outcomes Score (KOOS) questionnaire was used to assess the patient's perception of pain and function. The EuroQol-5D index scores were used to evaluate quality of life (QOL). Statistical analysis was performed using independent-samples student t test, Pearson chi-square test, multiple logistic regression, and multiple linear regression. In comparing UKA and TKA, the categories of KOOS indicated that patients favored UKA implants. No differences were found in improved QOL between the two treatments. Furthermore, men scored better than women in pain, activities of daily living, and function in sport and recreation.

Patil [16]. Total knee arthroplasty involves a change in articular surface, a loss of anterior and posterior cruciate ligaments, and altered neuromuscular patterns. Unicompartmental knee arthroplasty is stated to restore the knee to normal kinematic due to the preservation of one soft tissue and bone. Researchers hypothesize that UKA does not alter normal knee kinematics during stair ascent in a cadaver model. Four male and two female frozen cadavers between the ages 73 and 89 were used for this study. Tracking sensors were used to measure three-dimensional motion of the knee during stair-climbing. Tibiofemoral rotation, tibiofemoral varus and valgus, and femoral rollback as a function of flexion were recorded. Statistical analysis was performed using a repeated-measures multifactorial analysis of variance. The Bonferroni correction was used for the adjustment of three post hoc pair-wise comparisons. Researchers concluded that the fixed-bearing unicompartmental implantation had knee kinematic during flexion similar to that of the intact knee.

Lombardi [14]. With a goal of improving PROM, this study combines a minimally invasive surgical technique with a rapid recovery protocol. The purpose of this study is to address the following research question: how does UKA compare with TKA in terms of durability, incidence of complications and manipulations, recovery, postoperative clinical function, patient-perceived outcomes, return to sport and return to work? The Oxford Phase III mobile-bearing unicompartmental knee prosthesis (Biomet Inc, Warsaw, Indiana) was the implant used for all UKA. The Vanguard cruciate retaining prosthesis was used for all TKA patients. A variety of evaluative tools were used for rating patient-perceived outcomes: Knee

Society clinical rating system, Lower Extremity Activity Scale, and the Oxford knee score. Differences between variables were determined using the non-paired, two-tailed Student t test and the Pearson's chi-square test. Results indicated that there were similar numbers of revision and complications between UKA and TKA groups. The TKA group demonstrated a higher need for manipulation than the UKA group. The UKA demonstrated shorter hospital stays and a better mean ROM early on. The functional scores and Lower Extremity Activity Scale for the UKA group were higher than the TKA. The Oxford scores and Knee Society clinical rating system showed similar results for both groups.

Wiik [17]. Top walking speed (TWS) on an instrumented treadmill was used on TKA and UKA subjects to determine potential differences between the two surgical methods to healthy controls. Researchers have hypothesized that no differences between the gait of the different types of knee arthroplasty would be found and that both procedures would restore near normal gait. A total of 60 subjects a minimum of twelve-month post-operative were tested. An instrumented treadmill with force plates (Kistler Gaitway, Kistler Instrument Corporation, Amherst, NY) was increased incrementally until subjects were uncomfortable or had a change in gait performance. Results indicated that the UKA group walked significantly faster than the TKA group by eleven percent. Although the UKA group appeared to have a gait close to normal, not all aspects returned to normal gait. The hypothesis was partially supported in that only UKA restored gait closer to controls.

Surgeons are not persuaded by the UKA procedure due to its higher reported rate of revision and conflicting evidence [6, 7, 10, 15]. Two years following surgery, small or no differences were found between UKA and TKA patients [15]. Furthermore, PROM report only small differences between the two procedures [7, 15]. Although UKA patients exhibit gait patterns close to normal gait, not all parameters are restored [17].

APPENDIX A: RESEARCH SUBJECT INFORMATION AND CONSENT FORM

TITLE:	Biomechanical Comparison of Multi- and Single Radius Implant Designs During Level Walking and Stair Climbing Tasks
PROTOCOL NO.:	2014-018
SPONSOR:	Cris Stickley, PhD, ATC Honolulu, Hawaii United States
INVESTIGATOR:	Cass Nakasone, M.D. 888 South King Street Honolulu, Hawaii 96813 United States
SITE(S):	Straub Clinic & Hospital Bone and Joint Center 888 South King Street Honolulu, Hawaii 96813 United States University of Hawaii at Manoa PE/A Complex Room 231 1337 Lower Campus Road Honolulu, Hawaii 96822 United States
STUDY-RELATED PHONE NUMBER(S):	Cass Nakasone, M.D. 808-522-4232

Cris Stickley PhD, ATC
808-956-3798

This consent form may contain words that you do not understand. Please ask the study doctor or the study staff to explain any words or information that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

SUMMARY

You are being asked to be in a research study. The purpose of this consent form is to help you decide if you want to be in the research study. Please read this consent form carefully. To be in a research study you must give your informed consent. “Informed consent” includes:

- Reading this consent form
- Having the study doctor or study staff explain the research study to you
- Asking questions about anything that is not clear, and
- Taking home an unsigned copy of this consent form. This gives you time to think about it and to talk to family or friends before you make your decision.

You should not join this research study until all of your questions are answered.

Things to know before deciding to take part in a research study:

- The main goal of a <u>research study</u> is to learn things to help patients in the future.
- The main goal of <u>regular medical care</u> is to help each patient.
- No one can promise that a research study will help you.
- Taking part in a research study is entirely voluntary. No one can make you take part.
- If you decide to take part, you can change your mind later on and withdraw from the research study.
- The decision to join or not join the research study will not cause you to lose any medical benefits. If you decide not to take part in this study, your doctor will continue to treat you.
- Parts of this study may involve standard medical care. Standard care is the treatment normally given for a certain condition or illness.
- After reading the consent form and having a discussion with the research staff, you should know which parts of the study are experimental (investigational) and which are standard medical care.
- Your medical records may become part of the research record. If that happens, your medical records may be looked at and/or copied by the sponsor of this study and government agencies or other groups associated with the study.

After reading and discussing the information in this consent form you should know:

- Why this research study is being done;
- What will happen during the research;
- Any possible benefits to you;
- The possible risks to you;

- How problems will be treated during the study and after the study is over.

If you take part in this research study, you will be given a copy of this signed and dated consent form.

PURPOSE OF THE STUDY

The purpose of this study is to compare the function of patients implanted with either a multi- and single radius total knee arthroplasty design during level walking and stair climbing tasks.

TITLE:	Biomechanical Analysis of the Oxford® Unicompartmental Knee Implant Design During Level Walking and Stair Negotiation
PROTOCOL NO.:	2016-007
SPONSOR:	Cris Stickley, PhD, ATC Honolulu, Hawaii United States
INVESTIGATOR:	Cass Nakasone, M.D. 888 South King Street Honolulu, Hawaii 96813 United States
STUDY-RELATED PHONE NUMBER(S):	Cass Nakasone, M.D. 808-522-4000 Cris Stickley PhD, ATC 808-956-3798

This consent form may contain words that you do not understand. Please ask the study doctor or the study staff to explain any words or information that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

SUMMARY

You are being asked to be a participant in a research study. The purpose of this consent form is to help you decide if you want to be in the research study. Please read this consent form carefully. To be in a research study you must give your informed consent. “Informed consent” includes:

- Reading this consent form
- Having the study doctor or study staff explain the research study to you

- Asking questions about anything that is not clear, and
- Taking home an unsigned copy of this consent form. This gives you time to think about it and to talk to family or friends before you make your decision.

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- The main goal of regular medical care is to help each patient.
- No one can promise that a research study will help you.
- Taking part in a research study is entirely voluntary. No one can make you take part.
- If you decide to take part, you can change your mind later on and withdraw from the research study.
- The decision to join or not join the research study will not cause you to lose any medical benefits. If you decide not to take part in this study, your doctor will continue to treat you.
- Parts of this study may involve standard medical care. Standard care is the treatment normally given for a certain condition or illness.
- After reading the consent form and having a discussion with the research staff, you should know which parts of the study are experimental (investigational) and which are standard medical care.
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After reading and discussing the information in this consent form you should know:

- Why this research study is being done;
- What will happen during the research;
- Any possible benefits to you;
- The possible risks to you;
- How problems will be treated during the study and after the study is over.

If you take part in this research study, you will be given a copy of this signed and dated consent form.

PURPOSE OF THE STUDY

The purpose of this study is to compare the function of patients with the Oxford partial knee implant design during level walking and stair negotiation tasks.

APPENDIX B: PARTICIPANT HEALTH QUESTIONNAIRE

ID #: ____________________________________ **DATE**: ____________________

Participant Health Questionnaire:			
1	Has your doctor ever said that you have a heart condition and that you should only perform physical activity recommended by a doctor?	**YES**	**NO**
2	In the past month, have you had chest pain?	**YES**	**NO**
3	Do you lose your balance because of dizziness?	**YES**	**NO**
4	Have you ever been diagnosed with Parkinson's Disease?	**YES**	**NO**
5	Do you have a history of fainting?	**YES**	**NO**
6	Have you ever been diagnosed with a neurological disorder?	**YES**	**NO**
7	Do you have diabetes mellitus?	**YES**	**NO**
8	Do you have a bone or joint problem that could be made worse by physical activity?	**YES**	**NO**
9	Has a doctor ever diagnosed you with rheumatoid arthritis or osteoarthritis?	**YES**	**NO**
10	Within the six months, have you experienced an injury to your knee or any severe knee pain?	**YES**	**NO**
11	Have you had a previous hip, knee, ankle or foot surgery?	**YES**	**NO**

M / F **AGE:** ____________________

APPENDIX C: DATA COLLECTION FORMS

Anthropometric Data

Subject ID#: _______________ Date_________

Age________________ Gender: F / M

Data Collection Period 0 1 2 3 4 5

Patient's Operated leg: L / R Dominant Leg: L / R

Date of Surgery_________________

Weeks after Surgery________________

Vicon/Nexus Measurements

Weight (kg)	
Height (mm)	
Age (yrs)	
Left leg length (mm)	
Left knee width (mm)	
Left ankle width (mm)	
Right leg length (mm)	
Right knee width (mm)	
Right ankle width (mm)	

Data Collection Form

Subject ID#: _______________

Data Collection Period 0 1 2 3 4 5

Patient's Operated leg: L / R Dominant leg: L / R

Total Trials: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Walking Trials		
Trial	Which foot hit the plate	Walking Pace (s)
1	R / L	
2	R / L	
3	R / L	

Stair Ascent		
Trial	Which foot hit the plate	Walking Pace (s)
1	R / L	
2	R / L	
3	R / L	

Stair Descent		
Trial	Which foot hit the plate	Walking Pace (s)
1	R / L	
2	R / L	
3	R / L	

Manual Muscle Testing Data Collection

Subject ID#: _______________ Data Collection Period 0 1 2 3 4 5 6 7

Patient's Operated leg: L / R Tester: ______________________ Dominant Leg: L / R

	Left Leg						Right Leg					
	Trial 1 Score (ft-lb$_f$)	Pain Score (HHD/Jt)	Trail 2 Score (ft-lb$_f$)	Pain Score (HHD/Jt)	Trial 3 Score (ft-lb$_f$)	Pain Score (HHD/Jt)	Trial 1 Score (ft-lb$_f$)	Pain Score (HHD/Jt)	Trial 2 Score (ft-lb$_f$)	Pain Score (HHD/Jt)	Trial 3 Score (ft-lb$_f$)	Pain Score (HHD/Jt)
Hip abduction		/		/		/		/		/		/
Knee extension		/		/		/		/		/		/

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