TOTAL KNEE ARTHROPLASTY (TKA) POST-OP CLINICAL CARE GUIDELINE

Total knee arthroplasty (TKA), also known as a total knee replacement, is an elective surgical procedure to treat patients who experience pain and dysfunction from an arthritic knee joint. TKA is an effective option if the patient's pain does not respond to conservative treatment and has caused a decline in their health, quality of life, or ability to perform activities of daily living. This procedure removes the arthritic structures that make up the knee joint and replace them with artificial implants.

With advancements in modern medicine, there have been several effective surgical approaches developed for TKA. The surgeon will determine the best surgical approach to use for each individual. Patients are encouraged to participate in early mobilization while adhering to precautions in order to improve function and limit post-operative complications.

Disclaimer: Progression is time and criterion-based, dependent on soft tissue healing, patient demographics and clinician evaluation. Contact your orthopedic surgeon or surgical staff if questions arise. If you have questions about the clinical care guideline, please contact the author by calling our office at (614) 293-2385.

RED/YELLOW FLAGS

Red flags are signs/symptoms that require immediate referral for re-evaluation. Yellow flags are signs/symptoms that require modification to plan of care.

Red Flags	• Signs of DVT *(Refer directly to ED)*
	  ○ Localized tenderness along the distribution of deep venous system
	  ○ Entire LE swelling
	  ○ Calf swelling >3cm compared to asymptomatic limb
	  ○ Pitting edema
	  ○ Collateral superficial veins
	• Mechanical block or clunk *(Refer to surgeon for re-evaluation)*
	• Lack of full knee extension by 4-6 weeks *(Refer to surgeon for re-evaluation)*

Yellow Flags	• Persistent reactive pain or effusion following therapy or ADLs ○ *Decrease intensity of therapy interventions, continue effusion management and provide patient education regarding activity modification until reactive symptoms resolve*

Summary of Recommendations

Expectations	• *Outpatient rehabilitation is expected for every patient after discharge from hospital. Home Heath may be performed initially to increase mobility and achieve community distance ambulation prior to outpatient rehab.*

Precautions	• Signs of DVT *(Refer directly to ED)*
	  ○ Localized tenderness along the distribution of deep venous system
	  ○ Entire LE swelling
	  ○ Calf swelling >3cm compared to asymptomatic limb
	  ○ Pitting edema
	  ○ Collateral superficial veins
	• Mechanical block or clunk *(Refer to surgeon for re-evaluation)*
	• Lack of full knee extension by 4-6 weeks *(Refer to surgeon for re-evaluation)*
	• AD required for ambulation after post-op week 6 (MD follow up visit)

Weight Bearing Progression **and** **Criteria to Discharge Assistive Device**	• ROM: Full active knee extension; no pain on passive overpressure • Strength: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 SLR without quad lag • 60 sec of SL stance without compensation or pain • Weight Bearing: Demonstrates pain-free ambulation without visible gait deviation ○ Goal: DC AD by post-op week 3-6 weeks
Return to Driving	• L sided – 2 weeks • R sided – 4 - 6 weeks • See Phase 1 for further criterion

Range of Motion Progression	• Knee ext A/PROM:
	  ○ Neutral extension - week 2
	  ○ Knee extension symmetry between sides (as applicable) - week 4-6
	  ▪ *Prioritize achieving full knee extension AROM*
	  ○ Lack of full knee extension by 4 weeks →*Refer to surgeon for re-evaluation*
	• Knee flex A/PROM:
	  ○ 80 by 1 week
	  ○ 90 by 2 weeks
	  ○ 100-110 by 4-6 weeks
	  ▪ **if not at 110 by 6 weeks, refer to surgeon for possible re-evaluation*
	  ○ 120+ by 8-12 weeks
	  ▪ *Consider patient knee flexion ROM requirements based on social, work-related, religious functional needs → more aggressive ROM may be required. Refer to surgeon for guidance as needed.*

Patient Reported Outcomes (PRO)	Consistently collect at least one of the following PROs each visit. • Knee Injury and Osteoarthritis Outcome Score (KOOS) • International Knee Documentation Committee (IKDC) • Lower Extremity Functional Scale (LEFS)
Considerations Regarding Running and Plyometrics	**High impact activities such as plyometrics and running are generally not advised following total joint replacements. The first priority following these surgeries is to prevent damage to the new artificial joint and surrounding structures. Patients are advised to participate in low impact exercise/activities. ***Patients considering plyometrics with intent to resume running/sport should consult with their surgeon.*****

PHASE I: Day 1 Post-Op until D/C of Assistive Device (0-6 weeks)

Goals	• Protect healing tissue • Pain and edema control (recommend compression garments/shorts to assist) • DVT prevention • Improve pain-free ROM • Normalize muscle activation • Ambulate independently without AD • Independent with all ADLs

Precautions/Red Flags	• Signs of DVT *(Refer directly to ED)*
	  ○ Localized tenderness along the distribution of deep venous system
	  ○ Entire LE swelling
	  ○ Calf swelling >3cm compared to asymptomatic limb
	  ○ Pitting edema
	  ○ Collateral superficial veins
	• Mechanical block or clunk *(Refer to surgeon for re-evaluation)*
	• Lack of full knee extension by 4-6 weeks *(Refer to surgeon for re-evaluation)*
	• AD required for ambulation after post-op week 6 (MD follow up visit)

AD Progression	• Walker → less restrictive (cane) → no device as tolerated • Crutch use: 2→ 1→ 0 as tolerated • Goal: use of AD to minimize compensatory gait

Edema and Pain Control	• Cryotherapy at least 5x daily for the first week
	• Cryotherapy at least 3x daily for week 1-6
	• Compression hose post-op for 30 days (optional)
	• If returning to work in a predominantly seated position, elevation of knee recommended 10 min per hour (at least)
	• Girth Measurements:
	  ○ Changes in knee joint circumference of more than 1.63 cm represents a significant clinical improvement or deterioration (compared to a prior same side measurement)
	  ○ Knee girth should be determined by measurement of the transverse plane circumference of the knee at mid-patellar height in a supine position using a flexible plastic measuring tape

Range of Motion/Stretching	• Knee ext A/PROM:
	  ○ Neutral extension - week 2
	  ○ Knee extension symmetry between sides (as applicable) - week 4-6
	  ○ *Lack of full knee extension by 4 weeks→ *Refer to surgeon for re-evaluation*
	• PROM: Heel prop, bag hang, prone knee extension
	  ○ Goal: tolerate 60 min in extension daily (10-15 min per session)
	  ○ Add load as able
	• AROM: Prone/standing TKE, emphasize TKE with gait
	• Knee flex A/PROM:
	  ○ 80 by 1 week
	  ○ 90 by 2 weeks
	  ○ 100-110 by 4-6 weeks
	  ▪ By 6 weeks, ROM should be within 10 degrees of end range knee flexion goal
	  ▪ * if *not at 110 by 6 weeks, refer to surgeon for possible re-evaluation*
	• Review operative notes (if available) for pre-op ROM and/or ROM achieved under anesthesia.
	  ○ End range knee flexion goal = pre-op ROM and/or intraoperative ROM plus 10-15 degrees by 6 weeks
	• Stationary bicycle/recumbent stepper for ROM – no resistance
	• Manual patellar mobility, manual tibiofemoral mobility

<table>
<tr><td>Neuromuscular Control</td><td colspan="2">This section is priority over strengthening → do not progress to strengthening until muscle activation and isolated control is normalized
Target muscles: quadriceps, glutes, transverse abdominus, hamstrings</td></tr>
<tr><td>NMES Parameters → can be used post-op day 2 and following</td><td colspan="2">Early NMES (as early as postoperative day 2) and more frequent (5–7 times daily) application with longer cumulative time at the maximal intensity tolerated by patients improved outcomes
Home NMES unit may be beneficial (See Appendix A for necessary parameters)
Set up:
NMES pads are placed on the proximal and distal quadriceps
Patient sitting at edge of plinth/chair with knee in at least 60° flexion with shank secured with strap → more volitional forces can be produced in 60° flexion position as compared to long sitting with knee extended
The patient is instructed to relax while NMES generates at least 50% of their max volitional quadriceps contraction OR maximal tolerable amperage without knee joint pain
Measure max volitional contraction with handheld dynamometer
10-20 seconds on/ 50 seconds off x 15 min</td></tr>
<tr><td>Therapeutic exercise suggestions</td><td>Early Exercises
SAQ, LAQ, SLR, TKE
Weight shifts, SL balance
Mini squats; Leg/shuttle press
Heel raises, hamstring curls</td><td>Late Exercises
Step ups (fwd and side)
Heel taps
Balance progressions (unstable surfaces)
Posterior chain strengthening (hip, core)</td></tr>
<tr><td>Return to Higher Level Physical Activity</td><td colspan="2">UBE for cardio or recumbent stepper
Reference APTA CPG outlining more aggressive resistance strengthening earlier PRN</td></tr>
<tr><td>Aquatic Therapy</td><td colspan="2">With MD clearance, begin aquatic therapy once incision is healed (~6 weeks post-op)
Caution required with ambulation on pool desk due to slippery surfaces
Focus on knee ROM, normalizing gait, hip strengthening and stability
Can return to easy lap swimming (with the exception of elementary backstroke and breaststroke)</td></tr>
<tr><td>Criteria for Community Ambulation without AD</td><td colspan="2">ROM: Full active knee extension; no pain on passive overpressure
Strength: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform SLR 2x10 without quad lag
60 sec of SL stance without compensation or pain
Normalized gait pattern without assistive device – focus on TKE
Able to ascend/descent stairs with handrail or AD use
Goal: DC AD by post-op week 3</td></tr>
<tr><td>Return to Driving Progression</td><td colspan="2">MD clearance
Usually:
L sided – 2 weeks
R sided – 4 - 6 weeks
D/C Narcotics
RLE - Perform SLR 2x10 without quad lag
Driving step test (See Appendix B)</td></tr>
<tr><td>Criteria to Progress to Phase II</td><td colspan="2">Normalized gait pattern for community ambulation (≥800 ft) without AD
Knee ext normalized, knee flexion to 100-110 degrees
SLR 2x10 without quad lag
Minimal to no reactive pain and swelling with ADLs and PT exercises
Muscle activation and isolation is normalized</td></tr>
</table>

PHASE II: Return to Pain Free ADLs (6-12 weeks)

Goals	• Restore full PROM and AROM • Progressively improve strength of the affected LE musculature (core and LE muscles) • Normalize postural/pelvic and LE control with DL and SL activities • Normalize gait at preferred walking speed for community distances • Perform ADLs without pain or limitation	
Considerations for this phase	• Progress strengthening exercises and functional tasks as appropriate pending no reactive pain or effusion • Increase aerobic conditioning/endurance related tasks monitoring reactive edema	

Range of Motion/Stretching	Knee extension should be normalized
	Knee flexion A/PROM:
	• 100-110 by 4-6 weeks
	  ○ **if not at 110 by 8 weeks, refer to surgeon for possible re-evaluation*
	• 120+ by 8-12 weeks
	  ○ *Consider patient knee flexion ROM requirements based on social, work-related, religious functional needs → more aggressive ROM may be required. Refer to surgeon for guidance as needed.*
	• If ROM goals are not achieved by week 12, terminal stretches should be continued
	• Continue bicycle, bodyweight/closed chain stretches for ROM	

Edema Control	• Girth Measurements: ○ Changes in knee joint circumference of more than 1.63 cm represents a significant clinical improvement or deterioration (compared to a prior same side measurement)	
NMES Parameters	Criteria to d/c NMES ○ <20% quadriceps deficit on isometric testing using Biodex machine OR If a Biodex machine in not available: 1. 10 SLR without quad lag 2. Normal gait 3. 10 heel taps to 60 degrees with good quality 4. 10 rep max on LP and similar effort bilaterally 5. Inability to break quad MMT	
Cardiovascular Exercises	• May progress time on upright bike as tolerated (ensure pt can perform 30 min with minimal resistance and without symptoms prior to adding resistance. Decrease time to ≤15 min when adding resistance) • May begin elliptical when pt demonstrates adequate quad control, hip and knee extension, gluteal activation • Encourage continued progression of low impact activities for cardiovascular fitness and community endurance → gradual return to strengthening regimen with therapist guidance • Gradual return non-impact exercise such as: tai chi, aquatic exercise, Pilates → with therapist guidance	

Therapeutic Exercise	• Graded and multi-planar progressions:
	  ○ step ups
	  ○ step downs (eccentric focus)
	• Squat: Progress ROM and load
	• Open Chain knee extension
	• Resisted hamstring curls
	• Progressive LP/shuttle
		• Side steps with band
		• Multi-planar lunges
		• Resisted walking
		• Advanced bridges
		• SLS and balance progressions
		  ○ unstable surface, ball toss, EC, etc.
		• Advanced core exercises

Criteria for Discharge **(or to Progress to Phase III once MD clearance is provided)**	• Symmetrical and pain free knee ROM to meet the demands of patients activities • 5/5 LE and hip strength with MMT • Symmetrical DL squat to at least 70 degrees knee flexion • Good quality movement as graded on Forward Step Down Test (**Appendix C**) • Normalized gait pattern for community distances of ambulation

PHASE III: Pain Free ADLs to Return to Recreational Activities (12-24 weeks)

This phase is only required for patients who wish to participate in recreational sport outside of general therapeutic exercise. Patients who do not plan on sport participation can be discharged with maintenance program following completion of Phase II.

MD clearance is required for participation in impact activities.

Goals	• Correct abnormal/compensatory movement patterns with higher level multi-planer strengthening activities • Optimize neuromuscular control/balance/proprioception • Increase volume/intensity of aerobic activities • Initiate progressive plyometric activities (per clearance of physician) • Progressively return to sport or prior/desired level of function
Precautions	• Avoid sacrificing quality for quantity during strengthening • Ensure patient maintains full flexibility and pain-free ROM as strength continues to increase • Monitor/minimize reactive edema when increasing demand of task • Closely monitor return to sport progression
Range of Motion	• ROM should be checked periodically to ensure that loading the knee with new exercises does not alter neuromuscular response and normal joint mechanics • If ROM goals are not achieved by week 12, terminal stretches should be prioritized
Therapeutic Exercise	• Continue progressive LE and core strengthening (DL→ SL for closed and open chain exercises) • LE strengthening tasks progressed to multi-planer movements emphasizing core stability and hip/knee control • Core strength tasks progressed to emphasize rotational tasks (chops/lifts, etc) • Proprioception progressed with variability of surfaces, perturbations, UE or trunk movements • Progression towards sport-specific tasks as indicated
Plyometrics and Running	**High impact activities such as plyometrics and running are generally not advised following total joint replacements. First priority following these surgeries is to prevent damage to the new artificial joint. Due to lack of evidence on how high impact activities affect the integrity of artificial joint replacement, patients are advised to participate in low impact exercise/activities. Patients considering plyometrics with intent to resume running should consult with their physician.** • **See Appendix D (only for appropriate patients with MD approval)**

Appendix A: Bag Hang

Emphasis on low load, long duration stretching

- *Goal: 60 minutes of bag hang time total per day.*
- *Ideally: 4x15 minutes (or greater) per day*

Appendix B: NMES Set Up

2 or 4 pad set-up is appropriate

- NMES pads are placed on the proximal and distal quadriceps
- Patient: Seated with the knee in at least 60º flexion, shank secured with strap and back support with thigh strap preferred. The ankle pad/belt should be two finger widths superior to the lateral malleoli
- The patient is instructed to relax while the e-stim generates at least 50% of their max volitional contraction against a fixed resistance OR maximal tolerable amperage without knee joint pain
- 10-20 seconds on/ 50 seconds off x 15 min

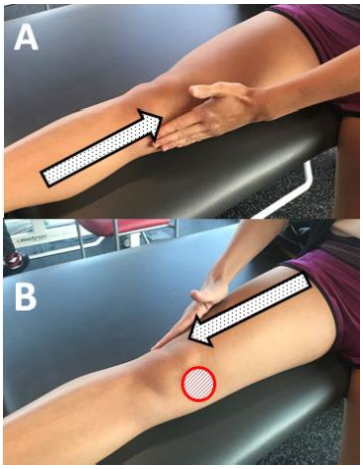
Appendix C: Stoke Test / Swelling Assessment

The Stroke Test

The stroke test is a great way to assess your swelling independently. The results of this assessment will help you decide what exercises are appropriate.

A. Using one hand, gently sweep the inside portion of your knee 2-3 times (pushing toward the hip joint).

B. On the outside portion of the knee, immediately sweep downward (toward the ankle). Watch the inside portion of the knee *(indicated by hashed circle in photo)* for a wave of fluid to appear during the downstroke.



Grading System

(Table adapted from Sturgill L et al, Journal of Orthopaedic & Sports Physical Therapy, 2009)

Test Result	Grade
No wave produced on downstroke	Zero
Small wave on inside aspect of knee with downstroke	Trace
Large bulge on inside aspect of knee with downstroke	1+
Swelling spontaneously returns to inside aspect of knee after upstroke (no downstroke necessary)	2+
So much fluid that it is not possible to move the swelling out of the inside aspect of the knee	3+

Indications for Activity

3+ or 2+	1+	Trace or Zero
Red Light	**Yellow Light**	**Green Light**
• No running, jumping or cutting or heavy lifting until swelling decreases to 1+ or less • Do not progress program until you speak with your therapist • Utilize swelling management strategies (ice, compression, elevation, NSAIDs)	• Proceed with caution • You may participate in running, jumping and normal lifting routine. • Check effusion before and after workouts • Utilize swelling management strategies (ice, compression, vation, NSAIDs)	• May participate in running, jumping and normal lifting routine without restriction • Continue to monitor swelling after activity

Appendix D: Driving Step Test

Purpose: To determine the patient's ability to safely return to driving an automatic vehicle. The step test simulates the patient's reaction to breaking.

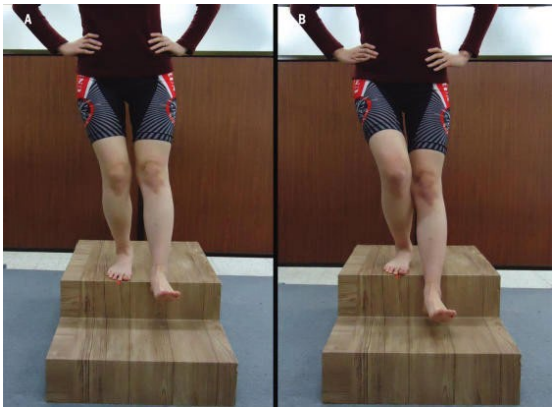
Procedure: The stepping test was performed with the patient seated and both knees and hips flexed at 90°. An oblong paper box measuring 2.5 × 2.5 × 30 cm was placed alongside the patient's right foot. The patient then had to step across either side of the box without touching it, and each step had to be firm planting of the heel. This test simulated the patient's reaction in braking, with the right foot being transferred from the accelerator pedal to the brake pedal. The test is performed in 10 seconds.

Results: Patient must perform 13 steps to pass the test

Reference: Hau R, Csongvay S, Bartlett J. Driving reaction time after right knee arthroscopy. *Knee Surg Sports Traumatol Arthrosc*. 2000;8(2):89-92. doi:10.1007/s0016700501

Appendix E: Forward Step Down Test

Definition of errors	Interpretation of errors	
• **Arm strategy:** subject uses an arm strategy in an attempt to recover balance (1 point) • **Trunk movement:** trunk leans right or left (1 point) • **Pelvic plane:** pelvis rotates or elevates on one side compared to the other (1 point) • **Knee position:** knee deviates medially and the tibial tuberosity crosses an imaginary vertical line over 2nd toe (1 point); knee deviates medially and the tibial tuberosity crosses an imaginary vertical line over medial boarder of the foot (2 points) • **Balance:** subject steps down on the uninvolved side or the subject's tested leg becomes unsteady (1 point)	0-1 errors	Good quality mechanics
	2-3 errors	Medium quality mechanics
	4+ errors	Poor quality mechanics



Reference: Park K, Cynn H, Choung S. Musculoskeletal predictors of movement quality for the forward step-down test in asymptomatic women. *J Orthop Sports Phys Ther.* 2013;43(7):504-510.

Appendix F: Plyometrics and Return to Running

Plyometrics Patients considering plyometrics with intent to resume running should **consult with their physician** before beginning this phase.	**High impact activities such as plyometrics and running are generally not advised following total joint replacements. First priority following these surgeries is to prevent damage to the new artificial joint. Due to lack of evidence on how high impact activities affect the integrity of artificial joint replacement, patients are advised to participate in low impact exercise/activities.** Criteria to initiate plyometric program: ***Physician clearance required*** • Full, functional, pain-free ROM • >80% quad and hamstring strength compared to uninvolved LE • DL Squat 150% BW (leg press or barbell squat) • 10 forward and lateral step downs from 8" step with proper alignment (**Appendix C**) • Progressive weight bearing, DL→ SL demands • Shuttle plyometrics (DL→SL) • Forward hop and hold (uninvolved→ involved) • DL mini hops/place jumps • Proper take off/landing mechanics emphasized → NO knee valgus, good pelvic stability, soft/quiet landing with equal distribution of force • Modified agility work can be initiated if appropriate form/tolerance to activity in progressive plyometrics
Criteria for Return to Sport	***Physician clearance required*** • Strength: >90% compared to uninvolved LE • >90% BW with SL leg press • Demonstrates ability to simulate functional sport-specific movement • Patient reported outcome measures: Score >/= 90%

Return to Running

- ROM: full, pain-free joint ROM, symmetrical with the uninvolved limb
- Strength: MMT 5/5 OR Isokinetic or hand held dynamometry testing with 80% limb symmetry index for involved muscle groups and proximal muscle groups
- 10 forward and 10 lateral heel touches on 8-inch step with good mechanics (See **Appendix C**)
- Weightbearing: normalized walking gait mechanics and able to walk 20 minutes without increasing pain

Phase	Walk/Run Ratio	Total Time
1	4 min / 1 min	10-20 min
2	3 min / 2 min	10-20 min
3	2 min / 3 min	10-20 min
4	1 min / 4 min	10-20 min
5	• Jog every other day until able to run 30 consecutive minutes • Begin with 5 min walking warm up • End with 5 min walking cool down	

General Guidelines

- Allow at least one day of rest between runs
- Gradual increase in distance is priority before increased pace
- It is common for runners to experience increased pain and/or reactive edema at least x1 during this return to run progression. When pain occurs, runner must stop running immediately and rest at least 1 day before restarting program. With restart, perform last walk/jog ratio cycle completed pain free x2 before attempting the previously painful ratio cycle.

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Reviewers: Nicholas Greco, MD
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References

- Bandholm T, Wainwright TW, Kehlet H. Rehabilitation strategies for optimisation of functional recovery after major joint replacement. J Exp Orthop. 2018 Oct 11;5(1):44.
- Barber-Westin SD, Noyes FR. Aerobic physical fitness and recreational sports participation after total knee arthroscopy: a systematic review. *Sports Health*. 2016; 8(6): 553-560.
- Dagneaux L, Bourlez J, Degeorge B, et al. Return to sport after total or unicompartmental knee arthroplasty: an informative guide for residents to patients. *EOR*. 2017; 2: 496-501.
- Donec V, Kriščiūnas A. The effectiveness of Kinesio Taping® after total knee replacement in early postoperative rehabilitation period. A randomized controlled trial. Eur J Phys Rehabil Med. 2014 Aug;50(4):363-71.
- Ghazinouri R, Rubin A, Congdon W. Total Knee Arthroplasty Protocol. Copyright 2012. The Brigham and Women's Hospital, Inc., Department of Rehabilitation Services. Pages 1-7. Accessed online 10/20/2018.
- Ho JC, Stitzlein RN, Green CJ, et al. Return to sports activity following UKA and TKA. *The Journal of Knee Surgery*. 2016; 29(3): 254-259.
- Jakobsen TL1, Christensen M, Christensen SS, Olsen M, Bandholm T. Reliability of knee joint range of motion and circumference measurements after total knee arthroplasty: does tester experience matter? *Physiother Res Int.* 2010 Sep;15(3):126-34.
- Jette DU, Hunter SJ, Burkett L, et al. Clinical Practice Guideline- Physical Therapist Management of Total Knee Arthroplasty. *Phys Ther*. 2020;100(9):1603-1631. doi:10.1093/ptj/pzaa099
- Kornuijt, A., de Kort, G.J.L., Das, D. *et al.* Recovery of knee range of motion after total knee arthroplasty in the first postoperative weeks: poor recovery can be detected early. *Musculoskelet Surg* **103,** 289–297 (2019). https://doi.org/10.1007/s12306-019-00588-0
- Lazar TA, Edelmann M, Awiszus F, Lohmann CH. Surgical site, gender, and place of residence influence the time to resume driving after total joint arthroplasty. *Arch Physiother*. 2021;11(1):16. Published 2021 Jun 29. doi:10.1186/s40945-021-00111-4
- Na A, Richburg K, Gugala Z. Clinical Considerations for Return to Driving a Car following a Total Knee or Hip Arthroplasty: A Systematic Review. *Biomed Res Int*. 2020;2020:8921892. Published 2020 Jul 6. doi:10.1155/2020/8921892
- Park K, Cynn H, Choung S. Musculoskeletal predictors of movement quality for the forward step-down test in asymptomatic women. *J Orthop Sports Phys Ther.* 2013;43(7):504-510.
- Patterson Sturgill L, Snyder-Mackler L, Manal, TJ, Axe MJ. Interrater reliability of a clinical scale to assess knee joint effusion. *Journal of Orthopaedic Sports Physical Therapy*. 2009; 39: 845-849.
- Pozzi F, White DK, Snyder-Mackler L, Zeni JA. Restoring physical function after knee replacement: a cross sectional comparison of progressive strengthening vs standard physical therapy. Physiother Theory Pract. 2018 Jun 7:1-12.
- Rupp S, Wydra G. Rehabilitation following total knee replacement. Conservative orthopedics and sport science. Orthopade. 2012 Feb;41(2):126-35.
- Ryan L. Mizner, PhD, PT, Stephanie C. Petterson, PhD, PT, Katie E. Clements, PT, DPT, Joseph A Zeni, Jr., PhD, PT, James Irrgang, PhD, PT, ATC, and Lynn Snyder-Mackler, ScD, PT, ATC. Measuring Functional Improvement after Total Knee Arthroplasty Requires both Performance-Based and Patient-Report Assessments: A Longitudinal Analysis of Outcomes. *J Arthroplasty*. 2011 Aug; 26(5): 728–737.
- Vanderthommen M, Duchateau J. Electrical stimulation as a modality to improve performance of the neuromuscular system. Exerc Sport Sci Rev. 2007 Oct; 35(4):180-5.