TASK ANALYSIS FOR MEASURING MOBILITY AND RECOVERY FOLLOWING RIGHT-SIDED TKA: TOWARD DETERMINING DRIVER READINESS

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Summary: Following a right-sided total knee arthroplasty (TKA), standard clinical recommendations for patients is to refrain from driving for 6 weeks. Clinical assessments of recovery include mobility tests but do not specifically assess fitness to drive. As a first step in assessment of driver readiness, this study aimed to compare vehicle entry behaviors and mobility assessments between TKA patients and healthy controls. 18 participants (9 TKA participants) completed three in-laboratory visits where they completed mobility tests and entered a full-cab car. Videos of vehicle entry were reviewed and annotated for time—timed vehicle entry (TVE)—and to categorize entry mode. TVE was significantly slower for TKA participants before surgery and 3 weeks after the procedure ($p < 0.05$) but not 6 weeks after ($p < 0.05$). TVE was positively correlated with timed up and go (TUG, $r = 0.65$, $p < 0.05$) and negatively correlated with right knee range of motion (ROM, $r = -0.5$, $p < 0.05$). Range of motion was not significantly different across entry modes between TKA participants and controls. This study was not conclusive to the utility of TVE to replace ROM and TUG for driver readiness; however, this work demonstrated the use of a real-world task that is related to driving for providing patient recovery and behavioral information.

INTRODUCTION

Driving after Total Knee Arthroplasty

Patients are recommended to abstain from driving following a right-sided total knee arthroplasty (TKA), or total knee replacement surgery. While six weeks is the standard of clinical practice at the local medical institution, evidence for safe recovery supports the resuming of driving activities between 2-8 weeks as indicated by driving reaction time (MacLeod et al, 2013). The study of safe return to driving activities is not novel. The research spans back decades across different injuries and operations (Giddins & Hammerton, 1996; Nunez & Giddins, 2004). However, a time for driver readiness is not clearly defined for patients following a right TKA. Our current medical institution observes a 6-week period for patients to abstain from driving. During these 6 weeks, patients work to regain their range of motion and strength.

Driving Safety

Driving safety can be measured in a simulated setting to protect the participants from harm (Dawson, Anderson, Uc, Dastrup, & Rizzo, 2009; Fisher, Lee, Rizzo, & Caird, 2011; Schwebel et al, 2007). While simulated driving assessments may not be feasible for every patient following an operative procedure, an understanding of what physical deficits contribute to the compromised safety can guide assessments of patient recovery progress indicating the patient is safe to resume driving activity. Currently, mobility assessments such as the timed up and go (TUG) and joint range of motion (ROM) are used to assess patient recovery (Mizner, Petterson, & Snyder-Mackler, 2005; Stevens, Mizner, & Snyder‐Mackler, 2003). However, there may be a task related to both mobility and driving that could inform providers on driver readiness and recovery. For this study the type of vehicle entry mode, time to enter the vehicle, and scores on standardized mobility tests were used to compare mobility between patients and controls. This was an effort to determine if assessment of driving-related behavior (vehicle entry) could similarly differentiate TKA patients from healthy controls compared to standard mobility tests or provide additional assessment of patient recovery and mobility.

This study aimed to test hypotheses that 1) timed vehicle entry and timed up and go for drivers undergoing Right-Sided TKA surgery are longer compared to control participants, 2) vehicle entry mode is related to joint range of motion and 3) timed vehicle entry is correlated with clinical assessment scores (timed up and go and joint range of motion).

METHODS

Participants

This study enrolled 24 participants, including 13 participants undergoing Right-Sided TKA surgery and 11 comparison participants without mobility impairment due to major joint injuries. Comparison drivers were age, gender, and education matched to Right-Sided TKA participants. Three participants that did not complete all three sessions and their matches were not included in the analysis for a total of 18 (9 control) participants. All participants gave informed consent to study participation according to institutional protocols.

Inclusion and Exclusion Criteria. All participants were legally licensed, active drivers between 35-76 years of age. At induction, participants underwent a medical history screening. Major confounding medical conditions were excluded, including neuropathy, neurodegenerative disorders, arthritis, and significant functional impairment in mobility. All participants had safe vision for driving, including no visual field defects and near binocular visual acuity of <20/40. Comparison participants had no evidence of mobility impairment as a result of major joint injuries. Right-sided TKA participants were recruited from the Department of Orthopedic Surgery and Rehabilitation at the medical center.

Study Procedures

Each participant completed three in-lab driving simulation visits: baseline within 3 weeks before surgery, 3 weeks post-surgery and 6 weeks post-surgery. Comparison participants completed their visits three weeks apart. Each study visit included mobility and simulated driving assessments. Standard mobility tasks included Timed Up and Go (TUG) and joint range of motion (ROM) measurement. Starting in a seated position, for TUG participants were timed while: standing up, walking 10 feet, walking back to the armless chair, and sitting. For ROM, seated patients began with their knee bent and feet flat on the floor then were asked to lift their foot to extend their leg to the highest comfortable position. Researchers used a goniometer to capture the range from 90 degrees to the location at the end of the patient's available movement. The Timed Vehicle Entry (TVE) task was completed in SENSEI (Simulator for Ergonomics, Neuroscience, and Safety Engineering, and Innovation), a DriveSafety RS-600 Research Simulator based on a 2004 Ford Focus cab. Video footage was obtained during the vehicle entry task using a Nikon D3300 DSLR camera mounted on a tripod five-feet from the driver's door to encompass the vehicle ingress of the participant. Participants stood three-feet from the driver door, their bodies parallel to the cab body (facing the same direction as the vehicle), and were instructed to approach the driver's seat and enter the car as they normally would. The TVE videos were annotated during a post hoc task analysis using MATLAB software (MATLAB R2018a). Video coders used the five hierarchical ingress strategies described by Ait El Menceur et al. (2008) to annotate the videos. Three strategies involved participants making seat contact beginning on a single-limb: 1) lateral sliding strategy, 2) backward motion strategy; and two strategies involved seat contact with double-limb support: 3) forward motion strategy, 4) trunk forward strategy, and 5) trunk backward strategy (Figure 1)(El Menceur, Pudlo, Gorce, Thévenon, & Lepoutre, 2008). Coders watched the videos and annotated the task for duration and vehicle entry mode. Videos were double-coded by independent reviewers to ensure inter-rater reliability. A third reviewer completed an independent review upon a disagreement.

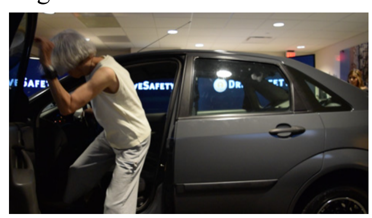
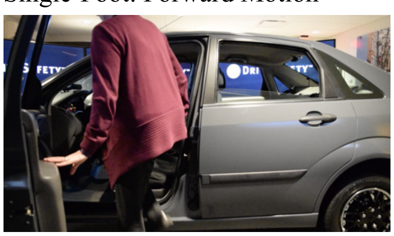
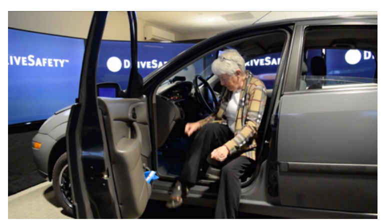
1	Single-Leg: Lateral Sliding 	2	Single-Foot: Backward Motion 
3	Single-Foot: Forward Motion 	4	Double-Foot: Trunk Forward 
5	Double-Foot: Trunk Backward 		

Figure 1. Example pictures of each Vehicle Ingress Mode

Statistical Methods

Vehicle entry modes and TVE were analyzed for agreement using interclass correlation coefficients (ICC) using a two-way random effects model with absolute agreement. Mode was analyzed for a single measurement. TVE was analyzed for a mean of multiple raters. Task scores for each visit and the change in scores were compared using paired t-test between TKA participants and their HCs. Chi-squared analyses were used to compare the mobility tests by vehicle entry modes and group (TKA vs HC). Pearson correlations were used to measure the relationship between mobility tests and TVE. Analyses were conducted with SAS Studio (SAS 9.4).

RESULTS

For the TVE, the coders demonstrated an *ICC* = 0.94 indicating high agreement among the coders. The agreement among the coders for the vehicle entry mode was lower with an *ICC* = 0.58. TKA participants had significantly lower TUG scores compared to the healthy control matches at each visit ($p < 0.05$). TVE at the first and second visits was significantly longer for TKA participants than healthy control matches ($p < 0.05$).There was no statistical difference in TVE between the TKA participants and their matched controls at the third visits ($p > 0.05$).

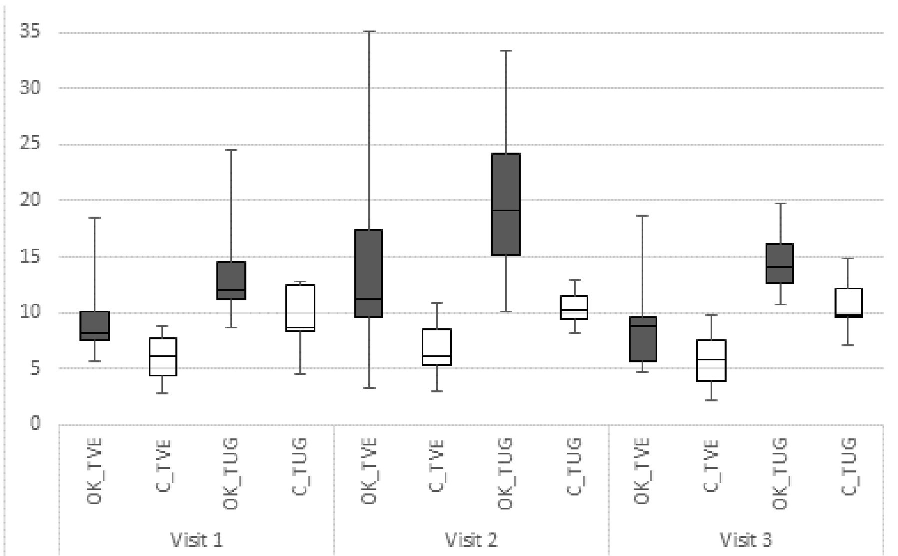


Figure 2. Comparison of Task Times between TKA and Matched Control (C) Patients

Additionally, for the change in TVE between visit 1 versus 2 and 1 versus 3, there was no statistically significant difference between TKA participants and healthy controls ($p > 0.05$).

Table 1. Single vs Double Limb Entry Mode

Limb Entry Mode	Participants		
	HC	TKA	Total
Single-Limb	22	18	40
Double-Limb	5	9	14
Total	27	27	54

A majority of the participants used single-limb entry modes compared to the double-limb entry modes (Table 1). However, for participants using the single-limb verses double-limb entry method, there was no statistical difference in use between HC and TKA participants ($p = 0.342$). There was no difference in ROM between single- verses double-limb entry modes at any of the visits ($p > 0.05$). The vehicle entry mode did demonstrate a pattern for several TKA participants. There was more variation in the entry mode used for TKA participants compared to HC participants. Additionally, more TKA participants changed their entry mode at the second and sometimes third visit with more controls continuing with the same entry mode at all three visits (Figure 3).

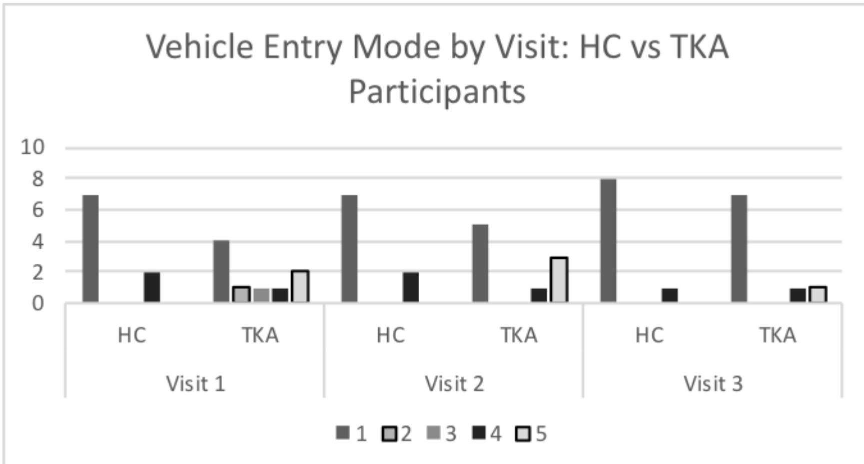


Figure 3. Comparison of Vehicle Entry Mode by Visit

While not significantly different between HC and TKA participants, ROM trended lower with higher variability—especially during visit 2—for TKA participants (Table 2). Across participants and visits, TVE demonstrated significant positive correlation with TUG and significant negative correlation with ROM (Table 2).

Table 2. Range of Motion (ROM) and Task Correlations

ROM	Visit 1 Mean, (SD)	Visit 2 Mean, (SD)	Visit 2 (Mean, SD)	Correlations	TVE, *r* (*p*-value)
HC	84.0 (8.6)	71.2 (7.1)	82.5 (7.0)	TUG	0.65 (<0.001)
TKA	80.7 (9.8)	69.0 (19.6)	77.9 (12.3)	ROM	-0.50 (0.001)

DISCUSSION

In this retrospective study, we used task analysis as a novel method to compare task performance with mobility between patients undergoing a TKA and matched healthy controls. As hypothesized, the HC participants performed their TUG significantly faster than the TKA participants completed the task. This is also consistent with past research using mobility tests (Mizner et al, 2005; Stevens et al, 2003). This occurred at all visits indicating reduced mobility by TKA participants before, 3 weeks after, and 6 weeks after the TKA. TVE was significantly longer for TKA participants before the procedure and 3 weeks after. There was no significant difference at 6 weeks post operation. Since TKA participants were not significantly slower at 6 weeks, this may indicate an average recovery point and be related to driver readiness. However, the difference between TVE at visit 1 verses visit 2 is not significantly greater than the difference between TVE at visit 1 verses visit 3 between HC and TKA participants. Therefore, there may be some natural variability in this task that is not related to surgery recovery. Additionally, we can see variability across task scores for TKA participants. This may indicate that although one recovery point may be adequate for many participants, it may not be appropriate to have a set driving restriction period for all TKA patients. TVE may be a better indicator of driver readiness, but not as sensitive as TUG to recovery.

While a majority of participants used the single-limb entry modes, there was no difference in use between TKA patients and the controls. ROM was not significantly different between individuals that chose single-limb entry modes. The choice of entry mode may be due to strength or balance instead of ROM. The double-leg entry modes never require a participant to stand with only one limb supporting their body. During single-limb entry, participants must support their body with one limb. Therefore, strength and balance may play a larger part in this task than ROM. Research has identified strength as a key recovery step to enhance functional performance (Mizner et al, 2005). The entry mode or different strength and balance tests may provide more information about driver readiness than the ROM. The TUG may be one of those tests since strength and balance are required to stand up and begin walking.

All participants were entering into the same vehicle. It was anticipated that participants post-surgery would have a reduced ROM and therefore have to change their entry mode.
It appears as though participants are changing vehicle entry mode which may be related to changes in TVE times between the healthy control matches. The change in mode may be the only way that TKA participants can enter he vehicle. In addition, while it may take longer, TKA participants are still able to complete the tasks, which potentially demonstrates compensation. Similarly, they may be able to compensate to overcome any barriers to driving in order to achieve appropriate break reaction times during driving. This is especially a possibility because a majority of driving tasks can be accomplished with ankle verses knee motions.

Both ROM and TUG are significantly correlated with TVE. As the ROM decreases, TVE increases. On the other hand, TUG and TVE are positively correlated. Therefore, TVE may be able to differentiate mobility similarly between participants. It may provide more predictive information for driver readiness. Since compared to HC participants, TKA participants at week 6 still had significantly lower TUG scores but not TVE scores, some TKA patients may be able to drive before the 6 weeks and others not until later.

Future Research. If vehicle ingress is related to driving safety, it could be used as a more specific real-world task to determine when patients are safe for resuming driving activities following a Right-sided TKA. It may be more difficult than the traditional clinical assessments, but also could be easier than a full driving simulation. A simple assessment such as TVE could be helpful for creating an individualized plan for rehabilitation, recovery, and return to driving following Right-sided TKA. Future research is planned to compare TVE to driver safety in simulation.

Limitations

This study did not control participants' use of the door or car frame for vehicle entry and did not include this as a covariate. With a small sample size, this would not have been feasible. However, this factor will likely need to be included for use as a standardized assessment. There was not a high consistency among coders for the entry mode; however, this was mitigated through a third blind review during which the reviewer always agreed with one of the two previous mode assignments.

CONCLUSION

While 6 weeks is the standard of clinical practice for abstinence from driving following a knee replacement procedure at the research institution, these preliminary results are reflective of the variability in the literature indicating drivers may be safe anywhere from 2-8 weeks following a Right-sided TKA. Traditional approaches to determine recovery in the clinical setting include measuring mobility. TVE could be a potential replacement of or addition to ROM and TUG to determine driver readiness with further validation and standardization. This work demonstrates an example of how a real-world task, vehicle entry, can be evaluated to describe mobility, recovery, and driving-related behavior of individuals.

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