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Review

What Is the Evidence on Which Physicians Can Rely to Advise Patients When They May Resume Driving after TKA? A Systematic Literature Review

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Abstract: Patients undergoing total knee arthroplasty (TKA) often ask when they can safely resume driving. Answering this question is an important matter, which might entail legal and insurance issues. In the present review, the following questions are addressed: What is the quality of the existing literature on this issue? When does the Brake Response Time (BRT) return to baseline values after right and left TKA? Are BRT components, reaction time (RT), and movement time (MT) equally affected after right and left TKA? Are there gender differences regarding the influence of TKA on BRT and its recovery? An electronic systematic search was performed on Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science, and PubMed. Ten studies investigating the effects of TKA on driving performance were included. The quality assessment was made with a 12-item assessment tool adapted from the "Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies" of the National Institute of Health. The quality of the existing studies varies, with all studies having methodological weak points. TKA causes an MT delay, which affects BRT negatively. The mean number of days for BRT to return to baseline values was 44 ± 19 (95% C.I. [29 to 58]) and 20 ± 15 (95% C.I. [2 to 38]) after right and left TKA, respectively. As shown by the wide 95% C.I. of the mean, these values can increase to higher numbers. Based on the weighted mean values, a driving abstinence of at least six weeks after right TKA and three weeks after left TKA should be recommended. Due to the discrepancies found in results, further high quality studies are necessary.

Keywords: total knee replacement; automobile driving; brake response time; movement time; reaction time; systematic review

1. Introduction

Total knee arthroplasty (TKA) is a common orthopedic surgical procedure with high success and long-term survival rates. The survival rates reported in the literature range from 90% at 15 years [1] to 82% at 22 years [2].

Similar to the United States [3], in Europe the number of patients undergoing TKA will probably increase in the future. This expected increase will present health care systems with new challenges due to increased costs.

With the development and implementation of enhanced rehabilitation programs that aim to improve recovery and reduce morbidity [4,5], the pre-, peri-, and post-operative management of these patients has been completely revised. The characteristics of enhanced rehabilitation programs (sometimes also called fast-track protocols) include in-depth patient education; modified anesthesia protocols; early mobilization (same-day mobilization); rapid resumption of activities of daily living; and multimodal pain therapy. A positive effect of this approach is a reduction in the number of days spent in hospital, with no increase in readmission rates due to complications [6,7]. The literature reports reductions in length of hospital stay from 10 to 2–4 days [8,9].

Depending on the health care system, patients are discharged from hospital to their homes or first redirected to inpatient rehabilitation institutions. Despite the existence of well-structured information about the ongoing rehabilitation process, patients want to know when they can safely resume driving a car. This is a common and relevant question, since the patient's mobility, for matters such as reaching their doctor or outpatient rehabilitation center, or returning to normal social life, may depend on the ability to drive a car. The return to safe driving is, therefore, of significant socio-economic importance.

In addition to legal and insurance questions, which might differ from country to country, there are psychomotor impairments induced by TKA that have to be taken into consideration when advising patients on this issue.

An important human factor in accident prevention research is the brake response time (BRT). The BRT is a measure of cognitive and psychomotor performance and has been used in traffic accident prevention research to assess driving capability in various populations [10–12]. BRT is defined as the time interval between the appearance of an unexpected road event (the stimulus) and the complete execution of an emergency stop. BRT can be divided into two main components: reaction time (RT) and movement time (MT). RT is defined as the time needed for signal perception, signal identification, and response selection. Accordingly, RT ends with the initiation of the motor component of the response—that is, with evidence of muscle activity or with a pressure reduction on the gas pedal. In contrast, MT is defined as the motor response to the signal. As a component of BRT, MT can be further subdivided into foot transfer time (FTT—time between removing the foot from the gas pedal and making first contact with the brake pedal) and the brake pedal traveling time (BPTT—the time between first contact with the brake pedal and its complete depression, or until a predefined force has been applied to the brake pedal) (Figure 1).

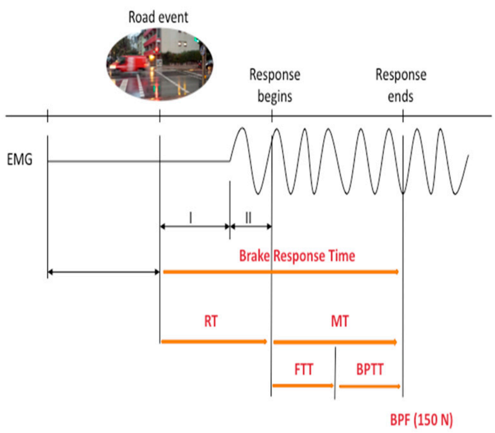

Figure 1. Components of Brake Response Time with Reaction Time (RT), Movement Time (MT), Foot Transfer Time (FTT), Brake Pedal Traveling Time (BPTT), Brake Pedal Force (BPF). I = Pre-motor RT; II = RT with already altered electromyographic activity but without observable movement. The end of MT could be defined with a force threshold of 150 N to be achieved on the brake pedal.

During car driving most drivers use the right leg to brake. To what extent left TKA affects the BRT of the right leg is not clear. The left leg serves a supporting function while moving the right leg, therefore it is possible that left TKA also interferes with the BRT of the right leg.

The purpose of this systematic review was to evaluate the quality of the existing literature on this issue. Furthermore, the following questions were to be answered: (1) When does the BRT of the right leg return to baseline values after a right TKA? (2) When does the BRT of the right leg return to baseline values after a left TKA? (3) Are BRT components (RT and MT) equally affected after right or left TKA? (4) Are there gender differences regarding the influence of TKA on BRT and its recovery?

2. Materials and Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Met-Analyses (PRISMA) statement [13]. An electronic systematic literature search was carried out in three databases: CINAHL, Web of Science, and PubMed (Medline).

2.1. Search Strategy

The databases were searched systematically. The last search took place on 10 October 2017. Dissimilar key words and medical subject heading terms (Mesh) were used and combined differently during electronic searches. The search terms and strategies used are shown in Appendix A.

2.2. Eligibility Criteria and Study Selection

Study selection was based on the surgical procedure (TKA) and on the study design. Only prospective studies investigating the effects of TKA on driving performance, with a repeated measure design, were selected. Cohort studies comparing patients at a certain point in time after TKA with controls were not included, since they did not investigate the changes directly evoked by the surgical procedure and the time at which BRT returned to baseline. Only studies retrieved in full and in English or German were assessed for eligibility.

2.3. Risk of Bias Assessment

A 12-item quality assessment tool adapted from the "Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies" of the National Institutes of Health (NIH, Bethesda, MD, USA) was used to assess the risk of bias [14]. The questions in the quality assessment tool focused on the evaluation of the internal validity of the studies.

In the quality assessment procedure, each study could get a maximum of 12 points. Studies were considered of "poor quality" (i.e., high risk of bias) if they scored between 0 and 4. Studies that scored between 5 and 8 points were considered to be of "fair quality". Studies that scored between 9 and 12 item-points were considered "good quality" (i.e., low risk of bias).

After quality assessment all research articles were critically assessed in order to answer the questions stated above, related to the purpose of this systematic review. Since the studies were conducted in different driving simulators, a comparison of the measured BRT, RT, and MT times was not possible. However, the time needed for these parameters to return to baseline (pre-operative) values was analyzed.

2.4. Data Collection Process

The data collection was performed using a data extraction sheet developed for the purpose. Data on the following items were extracted from each included study: name of the first author, publication year, variables assessed in the study (main outcomes), measurement points in time following surgery, sample size and constitution, mean age of the participants, and main results (Appendix B).

2.5. Statistical Analysis

The time (number of days) for BRT to return to baseline values was analyzed as well as the weighted mean number of days for BRT to return to baseline after right and left TKA. In the latter case, the weights represented the number of patients included for analysis from each study. Mean, standard deviation (SD), and 95% confidence interval (CI) of the mean were also calculated.

The statistical analysis was carried out using IBM SPSS Statistics for Windows, version 22 (IBM Corp., Armonk, NY, USA).

3. Results

After screening the search results of the three databases, 71 studies were located for detailed viewing. Of these, 29 studies were selected and 42 were excluded because they were related to other conditions than knee arthroplasty. A further 19 studies were then excluded: two were surveys [15,16], seven were recommendations, reviews, or systematic reviews [17–23], five were related to knee conditions other than TKA [10,24–27], and five studies were related to the effects of knee braces or lower limb immobilization devices on BRT [28–32]. The remaining 10 studies [33–42] matched the inclusion criteria and were included for analysis. For further details, see the Prisma flow diagram (Figure 2).

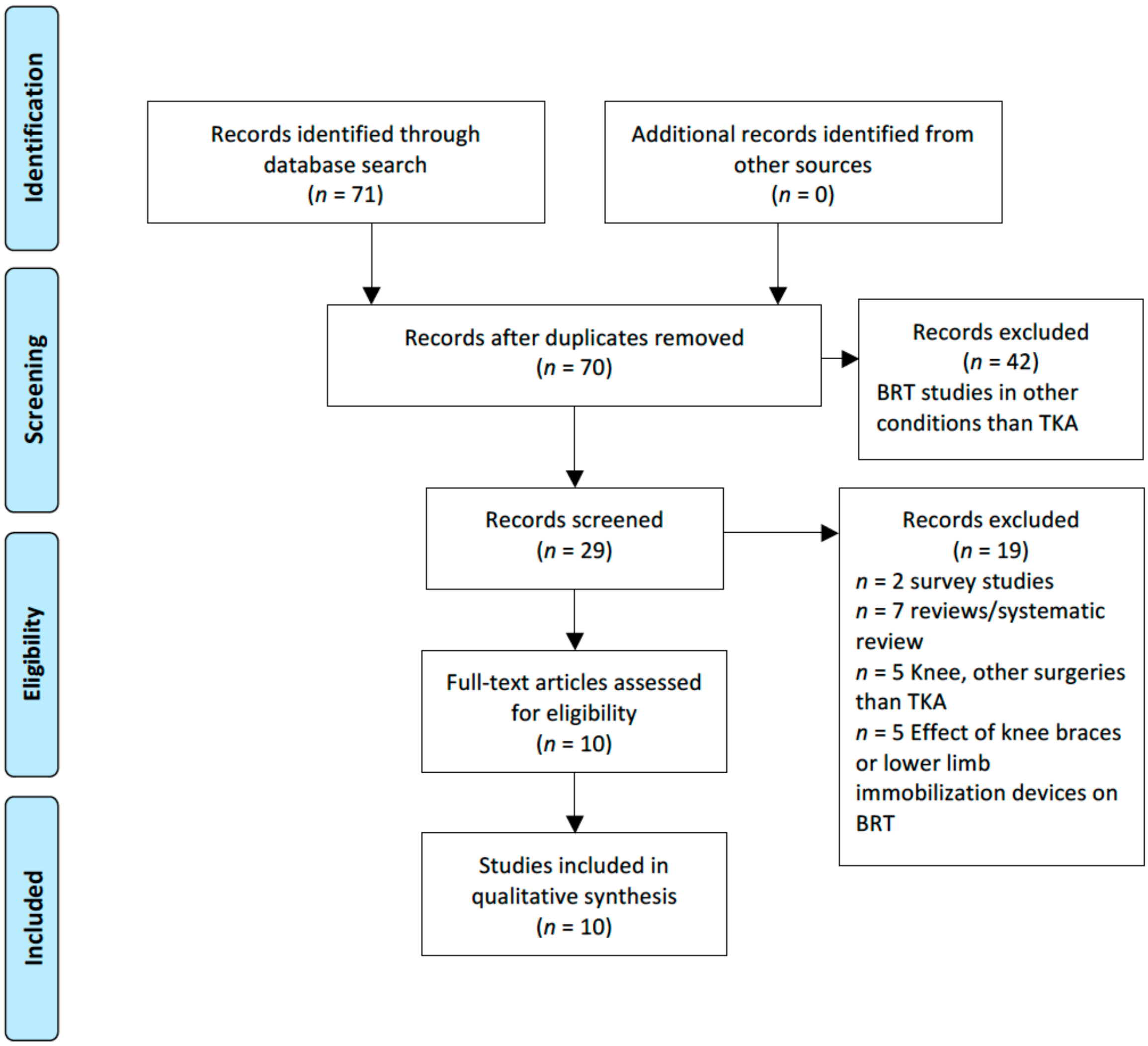

Figure 2. The PRISMA (Preferred Reporting Items for Systematic Reviews and Met-Analyses) flow diagram.

The ten studies comprised a sample of 309 patients who underwent TKA (197 right TKA, 99 left TKA, and 13 bilateral TKA) and whose BRT was measured preoperatively and at different points in time after surgery (Appendix B) in eight different car simulators. The mean age of the patients included in all ten studies was 66.6 years, ranging from 59.8 [37] to 74 [41] years.

3.1. Quality Assessment of the Included Studies

The overall quality of the studies varied and ranged from 3 points (poor quality) [41] to 10 points (good quality) [35], with four studies reaching a 9 point score (good quality) [36–39] (Table 1).

The quality assessment revealed weak points in all studies. There were quality problems in reporting patient recruitment flow, with only three studies presenting a patient flow diagram [35–37]. Furthermore, only three of the included studies [35,37,42] performed sample size justification analysis (statistical power). Five studies [33,34,38–40] did not provide information on dropouts and their reasons.

The sample characteristics may have been a source of bias in some studies as well. It is well known that age and gender influence BRT significantly [43]. However, the samples were often not balanced and gender comparisons were not carried out.

The mean age of the patients in the different studies ranged from 59.8 to 74 years in the studies by Liebensteiner et al. [37] and Spalding and colleagues [41], respectively. The age of the patients in the study by Dalury et al. [33] ranged from 47 to 81 years. This might be an excessively wide range, since it is known that RT increases with increasing age [44].

In one study [41] eleven non-drivers (37%) were included in the sample. For this reason, the results may be biased by selection of participants who were not familiar with the task (selection bias).

In another study [40], the sample consisted of 13 patients who underwent simultaneous bilateral TKA, along with 12 who had right TKA only and 6 who had left TKA only. The results of this study may also be biased, since the three groups were collapsed for statistical analysis. For this reason, this study was not included in the summary of studies investigating the effect of left TKA on BRT of the right leg.

Six of the ten studies did not describe the use of any method to filter the trial data before performing advanced statistical procedures (Appendix B).

BRT is affected by human, task-related, and environmental factors. The pedal layout is a good example of an environmental (ergonomic) factor. In the past [45,46], it was shown that the pedal layout (lateral separation between the accelerator and the brake pedal and the positive perpendicular separation of the brake pedal) influences BRT. Only two studies [38,39] provided information on the pedal layout used in their experiment. Different pedal layouts may influence BRT recovery after TKA differently. Therefore, and in order to make reproducibility of the results possible, future studies of this issue should always provide this information.

Three studies [36,37,41] reported dropout rates of over 20% between baseline and the last follow-up. One of the studies [36] reported high dropout rates between baseline and the first assessment (at two weeks) due to discomfort while sitting in the car simulator.

In three studies [34,38,39] the patients performed the BRT test-trials in more than one task. In two studies by Marques et al. [38,39] the patients performed a simple and a more complex task, with the task complexity being manipulated by adding a second movement to the first BRT task. In the study by Huang et al. [34] the patients performed the BRT task starting from three different prescribed speeds (50, 70, and 90 km/h). In all three studies the task sequence was not randomized, which may be a source of systematic bias.

Table 1. Quality Assessment Tool for the included studies (Adapted from the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies).

Criteria	Included Studies									
	Spalding, T.J.W. et al. (1994)	**Pierson, J.L. et al. (2003)**	**Marques, C.J. et al. (2008[a])**	**Marques, C.J. et al. (2008[b])**	**Liebensteiner, M.C. et al. (2010)**	**Dalury, F.D. et al. (2011)**	**Liebensteiner, M.C. et al. (2014)**	**Huang, H.-T. et al. (2014)**	**Jordan, M. et al. (2015)**	**Hernandez, V.H. et al. (2016)**
1. Was the research question clearly stated?	🔴	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
2. Was the study population clearly defined?	🔴	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
3. Were inclusion and exclusion criteria well described?	🔴	🔴	🟢	🟢	🟢	🔴	🟢	🔴	🟢	🔴
4. Were key potential confounding factors (e.g., age and gender) balanced?	🔴	🟢	🟢	🟢	🟢	🔴	🟢	🔴	🟢	🔴
5. Was patient recruitment period and flow well described?	🔴	🔴	🔴	🔴	🟢	🔴	🟢	🔴	🟢	🔴
6. Was a sample size justification, power description, or variance and effect estimates provided?	🔴	🔴	🔴	🔴	🔴	🔴	🟢	🔴	🟢	🟢
7. Were the timeframes between the repeated measures sufficient to detect changes from baseline?	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
8. Were the dependent variables (BRT, RT, MT) clearly defined?	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
9. Were the materials used to access the dependent variables (car simulator) well described, inclusive pedal layout description?	🔴	🔴	🟢	🟢	🔴	🔴	🔴	🔴	🔴	🔴
10. Were any measures taken to filter the data and remove possible outliers?	🔴	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🔴	🔴
11. Was loss to follow-up after baseline 20% or less?	🔴	NR	NR	NR	🔴	NR	🔴	NR	🟢	🟢
12. Are reports of the study free of suggestion of selective outcome reporting?	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Quality scores	3	5	9	9	9	5	9	5	10	7

NR = not reported; green circle = yes; red circle = no; Scores: 0–4 = Low quality (high risk of bias); 5–8 = Fair quality; 9–12 = Good quality (Low risk of bias).

3.2. When Does the BRT of the Right Leg Return to Baseline Values after Right TKA?

A total of 216 patients were tested in nine studies [33–37,39–42] after right TKA. The time (number of days) the patients needed for their BRTs to return to baseline values after right TKA varied in the different studies and ranged from 28 [33,34,42] to 84 days [35] (Figure 3). Two studies [37,40] found that the BRT of the patients returned to baseline values at 42 days after TKA and in two other studies [41,47] baseline values were reached 56 days after surgery.

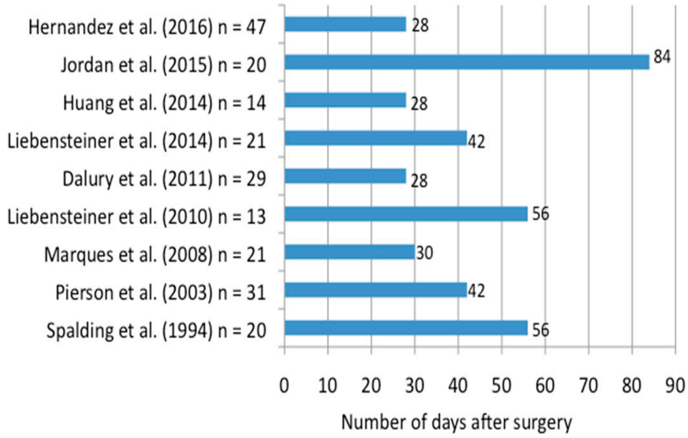

Figure 3. BRT recovery after right TKA.

The weighted mean number of days the patients needed for their BRT to return to baseline after right TKA was 41. The unweighted mean was 44 ± 19 days, 95% C.I. [29 to 58].

When considering the publication dates of the studies, there is a gap of 23 years between the first publication in 1994 [41] and the last one in 2016 [42]. Improvements regarding the operation technique and the pre-, peri-, and post-operative care of patients submitting for TKA could possibly explain the discrepancy between the time frame for a return to safe driving suggested by Spalding and colleagues [41] (56 days) and Dalury et al. [33] and Hernandez et al. [42] (28 days). Dalury and colleagues reported on a more contemporary knee arthroplasty, with the patients receiving periarticular injections for pain reduction, multimodal pain management, and enhanced rehabilitation after surgery. The authors reported that the BRT of 8 out of 29 patients reached baseline values by 14 days after right TKA. Similarly, Hernandez et al. [42] reported that all patients in their study were managed with spinal anesthesia, multimodal pain management, and rapid mobilization physiotherapy protocols. In their sample, 80% (39 patients) of the patients reached baseline values by 2 weeks (14 days) after TKA. The remaining 20% reached baseline by 4 weeks (28 days). The assumption that more contemporary TKA methods could decrease BRT recovery time was, however, not confirmed by two other studies published recently [35,37].

3.3. When Does the BRT of the Right Leg Return to Baseline Values after Left TKA?

Six [35–38,40,41] of the included studies tested the effects of left TKA on BRT of the right leg. For reasons mentioned in the quality assessment section, one of the studies [40] was excluded from this analysis. In the remaining five studies, a total of 93 patients were assessed in four different car simulators. The recommendations made by the different authors for safe return to car driving after left TKA show discrepancies as well. Three of the five studies found that BRT after left TKA returned to baseline values between the 7 and 14th day after surgery [36–38]. In contrast, Spalding and colleagues [41] reported that BRT was unchanged in comparison to pre-operative values at 28 days after surgery.

On the other hand, in the study by Jordan et al. [35], in which the first assessment after surgery was performed eight days after the intervention, the authors reported that BRT after left TKA was significantly increased by 2% at eight days, and was below baseline at week six (42 days after surgery) (Figure 4).

The weighted mean number of days the patients needed for the BRT of their right leg to return to baseline after left TKA was 19. The unweighted mean was 20 ± 15 days, 95% C.I. [2 to 38].

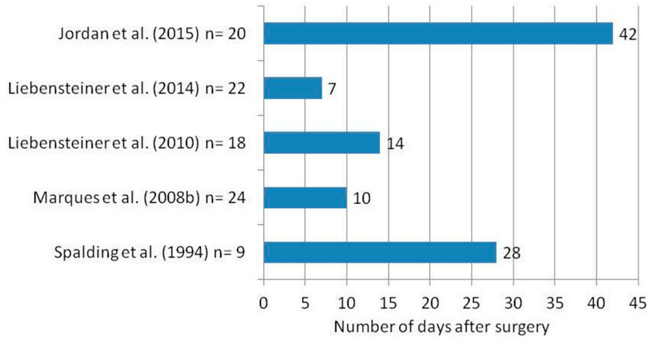

Figure 4. BRT recovery after left TKA.

3.4. Are BRT Components, RT and MT, Equally Affected after TKA?

Only six studies [33–35,38,39,41] used measurement systems and car simulators that enabled the assessment of the BRT components, RT and MT. TKA does not seem to affect central processes related to stimulus perception, stimulus identification, and response selection. Eight days after right or left TKA there were no significant RT changes in comparison to baseline values, as observed by Jordan and colleagues [35]. This result was reinforced by two other studies in which BRT was assessed at 10 days after surgery [38,39] and one study at 14 days [34]. Also, in the studies by Spalding et al. [41] and Dalury and colleagues [33], in which the first post-operative assessment was carried out at 4 weeks, no significant RT delays were observed.

All studies reinforced the hypothesis that TKA affects BRT by causing MT delays. The BRT delay after TKA is related to peripheral impairments during response execution. The motor response is affected by several variables, including the sitting position of the patient while performing an emergency stop in the car simulator [48]. In four studies [33,34,40,42] the patients performed the BRT trials sitting on a standard office chair, which is clearly different from the sitting position behind the steering wheel of a car.

3.5. Are There Gender Differences Regarding the Influence of TKA on BRT and Its Recovery?

No studies reported gender comparisons. For this reason, it is not possible to answer the question whether BRT characteristics and recovery were influenced by gender.

4. Discussion

Quick and safe return to driving after TKA is of important socio-economic value. The number of patients undergoing TKA surgery will increase in the coming years, with a greater number of patients being discharged earlier to their homes. Therefore, returning to safe driving will enable patients to get back to normal daily life sooner, thus saving the cost of hospitalization and avoiding dependency.

Many TKA patients ask their physician or surgeon when they can safely resume driving their cars. The available literature on this issue was assessed for its methodological quality and was critically reviewed. Overall, the sample sizes of the included studies were small, partly not justified by power analysis, and in some cases biased by selection.

In the study by Pierson and colleagues [40], the ANOVA results revealed no significant main effects for surgery side (simultaneous bilateral, left or right TKA). The authors decided to merge the results of all three groups for further analyses, which may have biased the statistical outcomes.

There was also no consideration of the possible effects of gender and age on BRT recovery after surgery, despite existing evidence that these patient-specific factors affect BRT [43].

Apart from the methodological weak points of each study, the results were sometimes widespread, showing the need of further research to clarify the discrepancies.

In the studies that assessed reaction time it was common to have outliers among the collected trial data. Outliers may be of two types: response anticipation attempts (subjects trying to anticipate the arrival of the stimulus) or distraction errors. Therefore, cleaning the data is important in order to remove outliers that may change the real mean BRT of the subjects. In further studies on this issue authors should consider the use of methods to clean outliers from the trial data.

Quality assessment revealed that future studies on this issue should provide a patient recruitment flow diagram and sample sizes should be justified by power analysis. Furthermore, gender-related analysis should be considered, since there is no available evidence on whether gender affects BRT recovery. Detailed information on the measurement system, including a description of the pedal layout and a clear definition of BRT and its components, should be provided. In studies using more than one task, the task sequences should be randomized; otherwise it is not possible to ensure that the results are not influenced by the task sequence.

The reasons for the different results across the studies may be related to patients' age and experience and the surgical techniques used. It is also possible that the different measurement systems and simulators used may have had an influence on the results.

As shown in Figure 1, the MT can be subdivided into FTT and BPTT. As the pedal layout influences FTT and BPTT, different pedal layouts may lead to different results.

Further research on this topic should consider the assessment of BPTT. BPTT is an important variable, since it is probably associated with a plantar flexion of the foot and an extension of the knee. BPTT should be assessed and defined as the minimum force threshold that has to be reached on the pedal at the end of the movement. An example of a BRT measuring system is shown in Figure 5, with the end of the MT being defined as a force threshold of 150 N on the brake pedal.

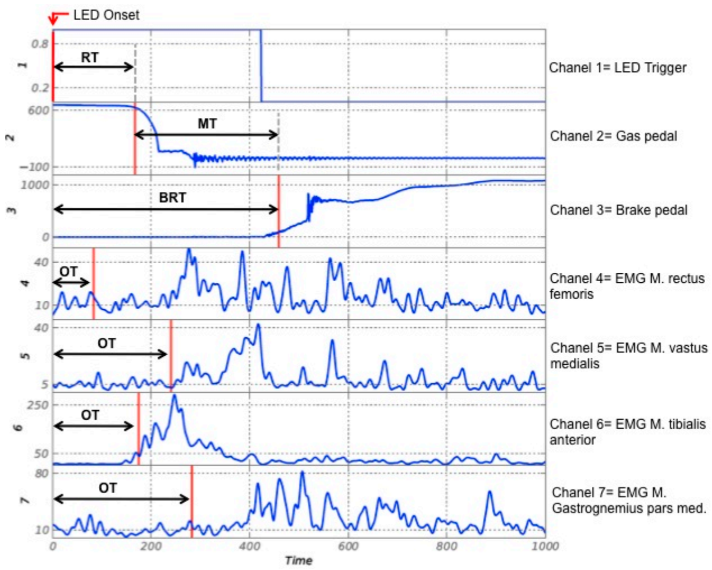

Figure 5. BRT and its components RT and MT, together with the activation thresholds of four muscles of the right leg during a brake response time trial. OT = Onset time. The beginning and the end of MT and the OTs were defined with algorithms. A force threshold of 150 N was used to define the end of BRT. A red light emiting diode (LED) was used as stimulus to initiate the task.

Between the 7th and 14th day after left and right TKA there were no negative effects detected on central aspects related to stimulus perception, stimulus recognition, and response selection, since RT was not significantly changed.

According to the results of the included studies, the BRT of the patients after primary right TKA may return to preoperative values between the fourth and eighth week after surgery. The results are, however, highly variable, making an evidenced-based recommendation impossible. Further research is required to clarify this question.

Clearly, BRT increases because of an MT increase. Therefore, rehabilitation programs that aim to enhance muscular activity may have a positive effect on BRT recovery, although this assumption is not yet supported by scientific evidence. In addition, there is no available evidence on which physicians can rely to advise patients after revision TKA or patients with post-operative complications.

Apart from the divergence of the results in the included studies, the authors share the opinion that recommendations on this issue should always be made carefully, taking into account the individual characteristics of the patient, his/her medical history, and the legal issues of the country.

5. Conclusions

Advising patients when they can resume car driving after TKA is an important practical matter, which might entail legal and insurance issues. In addition to the fact that legal frameworks may vary from country to country, the pre-surgical history and the post-operative individual course of the single patient have to be evaluated. TKA causes an MT delay and affects BRT negatively. Based on the weighted mean number of days the patients needed for their BRT to return to pre-operative (baseline) values, a six-week driving abstinence should be recommended after right TKA, provided there were no complications during the post-operative course of the patient. After left TKA, two weeks of driving abstinence are supported by three of the five studies that investigated this question. Due to the discrepancies found in results, further high quality studies are necessary.

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Author Contributions: João Barreiros and Carlos Marques. designed the review; Carlos Marques performed the literature search; Carlos Marques and Jan Cabri were responsible for the quality assessment of the included studies; Carlos Marques wrote the first draft of the paper; João Barreiros and Jan Cabri reviewed the manuscript for its scientific content.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Search Strategy

CINAHL

#1	Total knee replacement OR Total knee arthroplasty
#2	Knee replacement
#3	Knee prosthesis
#4	Arthroplasty
#5	#1 OR #2 OR #3 OR #4
#6	Brake response time
#7	Car driving
#8	Automobile driving
#9	Reaction time
#10	Movement time
#11	Braking
#12	#6 OR #7 OR #8 OR #9 OR #10 OR #11
#13	#5 AND #12

CINAHL (EBSCO host), 10 October 2017

Web of Science

#1	Brake response time
#2	Braking
#3	Automobile driving
#4	Movement time
#5	Arthroplasty, replacement, knee
#6	Total knee arthroplasty
#7	Reaction time
#8	#1 AND #6
#9	#3 AND #6
#10	#6 AND #7
#11	#7 OR #4 OR #3 OR #2 OR #1
#12	#6 AND #11

Web of Science, 9 October 2017

PubMed

#1	Total knee replacement (MeSH)
#2	Knee joint (MeSH)
#3	Arthroplasty (MeSH)
#4	Knee prosthesis (MeSH)
#5	#1 OR #2 OR #3 OR #4
#6	Automobile driving (MeSH)
#7	Braking
#8	Reaction time (MeSH)
#9	Movement time
#10	#6 OR #7 OR #8 OR #9
#11	#5 AND #10

PubMed, 10 October 2017

Appendix B.

Table A1. Overview of the Selected Studies by Publication Date.

References	Dependent Variables				Measurement Times (Weeks or Days)	Sample Size (n)	Mean Age (Years)	Main Results (* = Particularities)
	BRT	RT	MT	Force				
Spalding, T.J.W. et al. (1994)	Yes	Yes	Yes	Yes	Before, 4, 6, 8, and 10 weeks after	n = 29 (18 drivers; 11 non-drivers) 20 right TKA 9 left TKA	74 (61–83)	Right TKA: -RT remained unchanged at 4 weeks. -MT was 50% increased at 4 weeks; at 8 weeks returned to pre-op values. Left TKA: -BRT, RT, and MT remained unchanged 4 weeks after surgery. * High dropout rates: 27.5% started the study but did not finish it. * From 29 subjects included for analysis, 11 had been non-drivers.
Pierson, J.L. et al. (2003)	Yes	No	No	No	Before, 3, 6, and 9 weeks after	n = 31 (17M; 14W) 13 bilateral TKA 18 unilateral TKA: −12 right TKA −6 left TKA	68.6 (±7.6)	BRT: -12.5% quicker response at 6 weeks -17.5% quicker response at 9 weeks * Since 3 × 4 ANOVA revealed no significant differences in average BRT x laterality of TKA, the authors collapsed all patients across the variable "side of surgery" for all statistical analysis. For this reason, the results are probably biased.
Marques, C.J. et al. (2008)	Yes	Yes	Yes	No	Before, 10 and 30 days after	n = 21 21 right TKA: (9 M; 12 W)	69.1 (±7.8)	Right BRT: -was 9.01% increased at 10 days -was still 1.7% increased at 30 days (statistically not significant) RT: -no significant differences across the measurements MT: -was significantly increased at 10 days -at 30 days it was still significantly increased -high dropout rates (22% were not assessed at the 3rd measurement)
Marques, C.J. et al. (2008)	Yes	Yes	Yes	No	Before, 10 and 30 days after	n = 24 24 left TKA (13 M; 11 W)	63.2 (±8.5)	Left TKA: -BRT, RT, and MT were not affected 10 days after surgery
Liebensteiner, M.C. et al. (2010)	Yes	No	No	No	Before, 2 and 8 weeks after	n = 31 (14M, 17W) 13 right TKA 18 left TKA Control group n = 31 (12 M; 19 W)	65.7 (±10.2)	Right TKA: -BRT was not significant increased at 2 weeks -BRT decreased significantly from 2 to 8 weeks. Left TKA: -BRT was not significantly increased at 2 weeks -Significant decrease between 2 and 8 weeks * High drop-out rates between Pre-Op and 2 weeks due to discomfort while sitting in the car simulator. * Control group was not age and gender matched.
Dalury, D.F. et al. (2011)	Yes	Yes	Yes	No	Before, 4, 6, and 8 weeks after	n = 29 29 right TKA	66 (47–81)	-At 4 weeks all patients performed faster than preoperatively -RT: significantly faster at 4 weeks -FTT: no significant difference at 4 weeks

Table A1. *Cont.*

References	Dependent Variables				Measurement Times (Weeks or Days)	Sample Size (*n*)	Mean Age (Years)	Main Results (* = Particularities)
	BRT	RT	MT	Force				
Liebensteiner, M.C. et al. (2014)	Yes	No	No	No	Before, 1 and 6 weeks	*n* = 43 (22 M; 21 W) 21 right TKA 22 left TKA	59.8 (±7.5)	Right UKA (Unicompartmental knee arthroplasty): -BRT was significant increased at 1 week. -Baseline values were achieved at week 6 Left UKA: -BRT was not significantly changed at 1 week * High dropout rates: 26% of the patients assessed preoperatively dropped out at 6 weeks.
Huang, Hsuan-Ti et al. (2014)	Yes	Yes	Yes	No	Before, 2 and 4 weeks	*n* = 14 14 right TKA: (4 M; 10 W)	63.1 (±6.6)	Right TKA: -BRT returned to baseline at 4 weeks at a driving speed of 50 and 70 km/h -At a driving speed of 90 km/h the BRT was still significantly increased at 4 weeks. * Minimally invasive surgery (MIS) was used for all surgeries. All subjects were tested at three different speeds (50, 70, and 90 km/h). The order of performing at different speeds was not randomized. Are the patients performing at a 90 km/h speed slower as an effect of fatigue?
Jordan, M. et al. (2015)	Yes	Yes	Yes	Yes	Before, 8 days, and 6, 12, and 52 weeks	*n* = 40 20 right TKA: (10 M; 10 W) 20 left TKA: (8 M; 12 W)	69 (right TKA) 73 (left TKA)	Right TKA: -BRT was significantly increased at 8 days by 30% -Brake Force (BF) was significantly decreased by 35% -Baseline values were reached at week 12 Left TKA: -BRT was not significant increased at 8 days (2%) -BF was significantly decreased by 25% at 8 days -BRT below baseline at week 6 -11% were lost to follow-up
Hernandez, V.H. et al. (2016)	Yes	No	No	No	Before, 2, 4, and 6 weeks	*n* = 47 47 right TKA (48.3% M; 61.7% W)	67.5 (±10.0)	-BRT of 39 patients (80%) was at baseline by 2 weeks -20% reached baseline by 4 weeks * All patients managed with spinal anesthesia. Multimodal pain management and rapid mobilization physical therapy protocol were used.

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