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When is it Safe to Resume Driving Following a Right-Sided Hip or Knee Replacement?

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ABSTRACT

Background: Returning to safe driving is an essential aspect of the rehabilitation following total hip (THR) or total knee replacement (TKR). Making an emergency stop has been used in the past as the main criteria to assess fitness to drive following surgery.

Methods: We have tested the Total Brake Reaction Time (TBRT) before surgery and at different intervals post-surgery (1,2,4 and 6 weeks) using a driving simulator. A return to baseline TBRT was used as the criteria for safe driving status.

Results: Overall, 22 patients (11 males and 11 females), 14 in the THR and 8 in the TKR group. The median recovery time for the THR group was two weeks compared to 4.4 weeks for the TKR group ($p<0.034$). The overall failure rate of return to baseline was 14.3% for THRs and 62.5% for TKRs. Females had a significantly slower mean baseline TBRT (504ms) compared to males (414ms) ($p<0.046$) but had a faster median recovery time of 2 weeks compared to 3.3 weeks for males ($p<0.72$). However, we found a higher failure rate of return to baseline of 45.5% for females compared to 18.2% for males.

Conclusion: Due to a wide variation in the recovery of safe driving ability, we recommend that patients refrain from driving for 2-4 weeks following a hip replacement and 6-8 weeks following a knee replacement.

Keywords: hip arthroplasty, knee arthroplasty, total brake reaction time, driving ability, post-surgery timelines.

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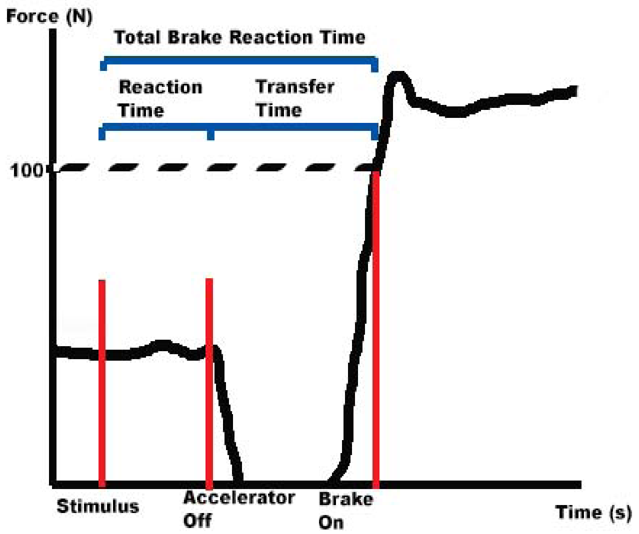
INTRODUCTION

Over the past 30 years, extensive research into how long patients take to recover driving ability after a total hip replacement (THR) or total knee replacement (TKR) surgery has been carried out. However, no clear clinical guidelines have emerged due to the different assessment criteria used.

In 1988 MacDonald and Owen [1] conducted the first known study of this nature using a variable called 'reaction time.' This was defined as the time from the onset of a visual stimulus until the patient reached a 100 Newton (N) force on the brake pedal. Further studies sub-classified this reaction time into two parts: the neurological recognition of the stimulus and the mechanical transfer time. Thus, 'reaction time' is now called 'total break reaction time' (TBRT), which is the sum of the 'reaction time' and 'transfer time' shown in Figure 1.

Most subsequent studies have used the total brake reaction time. However, the use of 100N brake pedal force has not been consistent. As a result, TBRTs achieved by patients have varied to a great extent making it difficult to determine whether patients have sufficient strength to perform an emergency stop.

FIGURE 1: TOTAL BRAKE REACTION TIME



As far as THRs are concerned, studies that have tested TBRT on patients before and after surgery go back to 1988 when MacDonald et al. found that most patients were safe to drive by eight weeks [1]. However, later in 2003, Ganz et al. suggested this time may be shorter, around 4-6 weeks [2], and in 2014 Jordan et al. published a study showing that most THRs had reached baseline by six weeks [3]. More recent studies (including cross-sectional studies and systematic reviews) have reported a quicker recovery around four weeks [4,5,6], but they have highlighted significant variations amongst patients recommending an individualized approach.

For TKRs, Spalding et al. in 1994 found that TBRT had not returned to pre-operative levels until eight weeks [7]. However, later in 2003, Pierson et al. published research showing that eight weeks may be too conservative and that patients were fit to drive after only six weeks [8]. More recent studies have reported that most patients had recovered sufficient TBRT to resume driving between 2 and 6 weeks following a TKR [9,10,11], but again there were significant variations amongst patients.

As described above, a significant issue when looking at the previous research in this area is the different definitions of the total brake reaction time. This makes combining the results of the literature difficult and hence the lack of consensus.

Many of these studies had a small number of participants, and large dropout rates resulted in limited statistical significance.

This study aimed to improve on past limitations and add new information in areas not previously studied. We used the definition of TBRT with a cut-off force of 100N.

We included early post-operative testing at 1 and 2 weeks to identify performance in motivated patients with fast recovery potential.

A qualitative questionnaire was designed to collect data around driving confidence and pain/stiffness/weakness symptoms at various time points. In addition, the aim was to record the patient experience concerning resuming driving following a joint replacement to explain the disparity in results.

Finally, this study is comparing THR and TKR surgery. Previous literature has studied a single operation and compared left and right-sided operations. This study looked at right-sided THR's and TKR's, as only the right leg operates the accelerator and brake in a motor vehicle, regardless of the side of the driver's seat.

METHODS

The aims of this study were as follows:

1. To measure the average time it takes for a patient following a THR or TKR to recover within 10% of their pre-operative baseline transfer time.
2. To look for differences in pre-operative baseline performance and recovery time between operation type and gender.
3. To analyze the patient experience of pain, perceived driving confidence, and other symptoms peri-operatively using a qualitative questionnaire.

INCLUSION CRITERIA

Patients who fulfilled the inclusion criteria (hip or knee arthritis, aged between 18 and 85 years, booked for right hip or knee replacement) were sent a letter of invitation to participate in the study along with an information sheet.

We also used controls with normal hips and knees.

ETHICS REVIEW

Ethical approval was obtained through the University of Otago Human Ethics Committee (Health) project ID: 00985.

Study Design

Primary Variables

For this research, there were both quantitative and qualitative outcome measures.

The primary variable was the transfer time, which measures the time from initiation of movement to achieve a brake pedal force of 100N.

The qualitative measured variable was a questionnaire completed by patients only at each test.

Testing Intervals

Participants have tested a total of 5 times during the study. A pre-operative measurement followed by 1, 2, 4, and 6 weeks post-operatively. At each test, they completed a questionnaire.

Controls were measured twice during the study: a baseline measurement and a final measurement six weeks later. Controls did not fill out questionnaires.

Testing Protocol

Baseline measurement

The accuracy of the baseline measurement is essential, as it is the measurement that every subsequent test is compared with. Therefore, we elected to measure the time to return to baseline instead of time to a specific benchmark brake reaction time. However, the baseline must reach a set of standards for the patient to be considered safe pre-operatively (MacDonald et al.) [1].

We used the following criteria:

1. The trimmed mean of their ten efforts must be below 700ms
2. A minimum of 8 out of 10 of these efforts must reach 100N.

A patient who did not provide a baseline measurement fulfilling these criteria was excluded from the remainder of the study as that person was considered an unsafe driver.

Post-operative Testing

The patients were tested at weeks 1, 2, 4, and 6 by a single assessor to avoid inter-assessor variability.

A patient who reached their baseline before the final 6-week test was monitored for above-baseline performance.

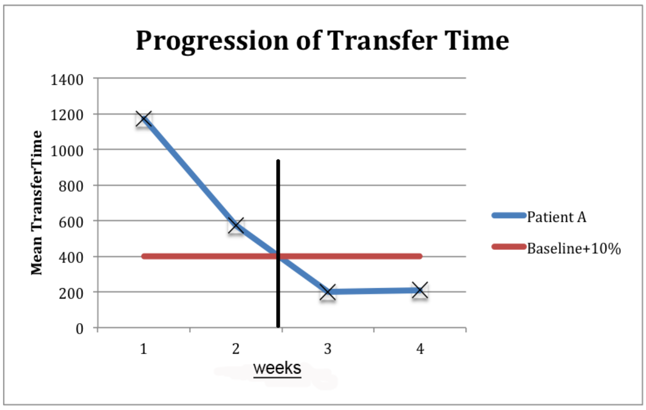
All data were recorded using the 'SENSIT test and measurement software (www.futek.com).

A patient's data was modeled on a line graph to calculate how many weeks they took to reach baseline.

Calculating Time to Baseline

Once the patient has completed all testing, their time to baseline was calculated and plotted on a graph with the mean transfer time on the y-axis and the number of weeks on the x-axis. Where they cross their baseline +10% is the point at which they achieved baseline. This is shown in Figure 2.

FIGURE 2: PROGRESSION OF TRANSFER TIME

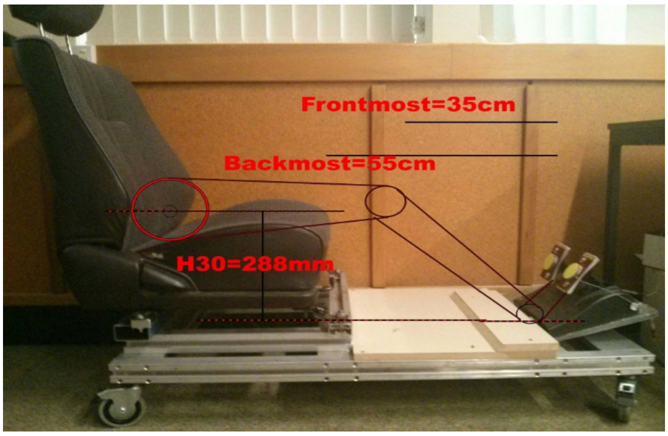


The Testing Rig

The Frame and Seat

The rig used in this study was custom built as a driving simulator for gaming consoles. We made some specific modifications to set the seat at a fixed height of 470mm from the floor (including mounted wheels) and an H30 (hip to vertical heel distance) of 288mm. The rails allowed the seat to be adjusted forward and back. Distance from the edge of the seat to the pedals was 35cm at the shortest and 55cm at the longest.

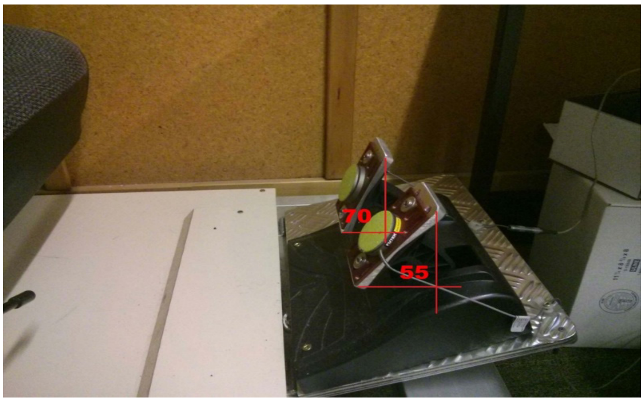
ILLUSTRATION 1: DIMENSIONS OF SEAT



The Pedals

The pedals used came with the original gaming rig (driving force GT range by Logitech). There was an accelerator and a brake pedal. The pedals were cut and mounted to a base plate. The resting angulation of the accelerator and the brake pedals are shown in the figure below.

ILLUSTRATION 2: RESTING ANGULATION OF PEDALS



The Sensors

There were two-pedal force sensors used in this rig: one on the accelerator and one on the brake pedal. These were purchased from FUTEK Ltd (model number LAU200 item number FSH00219). These had a maximum load of 25lb and a maximum sampling rate of 100 samples/second. A USB conversion kit was used to convert the output from the sensors into a USB format read by the testing laptop (USB 210 External USB Output kit).

The Questionnaire

Patients completed the following questionnaire at each test:

DRIVING QUESTIONNAIRE

Name:
Operation:
Weeks since operation: (pre,1,2,4,6)

Please answer all the questions based on how you feel today

1. How confident are you in your ability to perform an emergency stop? (1-10)

1--10
(not at all confident) (extremely confident)

Answer:

2. What would you say is the **main** factor affecting your ability to emergency brake? (a,b,c)

a. Pain
b. Stiffness
c. Weakness

3. On a scale from 1-10 how pain did you experience when performing an emergency stop today?

1--10
(no pain) (worst pain imaginable)
Answer:

4. Overall how comfortable would you feel if you were to return to driving today? (1-10)

1--10
(not at all comfortable) (extremely comfortable)

Answer:

Statistical analysis

We used the SPPS software package (IBM SPPS Statistics) to carry out statistical

analysis of variance using the one way ANOVA test and survival distribution using the

Log-rank test. Statistical significance was set at a p-value of <0.05.

RESULTS

Demographic Data

In the given time, 53 eligible patients were identified. However, 23 patients declined to participate, and 30 were entered into the study.

Nineteen patients (10 males and nine females) were entered into the THR group and 11 (4 males and seven females) into the TKR group. The average age of the two groups was not significantly different (THR: 67.4 SD 10.6 and TKR: 67.0 SD 9.4).

Of the 30 study participants, 26 subjects completed satisfactory baseline measurements. Still, four were lost to follow up before the first recovery test (2 due to severe pain, one due to persistent low blood pressure, and one loss of contact), leaving 22 patients (11 males and 11 females).

Survival Analysis by Operation

Of the 22 patients, 15 returned to within 10% of their baseline measurement in the given time. The overall failure rate of return to baseline was 31.8% (THR 14.3% and TKR (62.5%) (Table 1).

TABLE 1: RETURN TO BASELINE SURVIVAL ANALYSIS BY OPERATION

Operation	Total N	N returned to baseline within testing period	N failed to return to baseline within testing period	
			N	Percent
Total Hip Replacement	14	12	2	14.3%
Total Knee Replacement	8	3	5	62.5%
Overall	22	15	7	31.8%

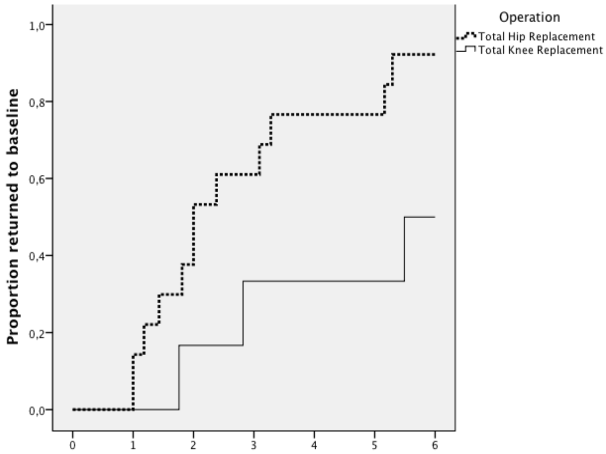
The TKR group observed a significantly slower recovery and a higher proportion of patients not returning to baseline within six weeks than the THR group (Table 2).

Table 2: Median time to return to baseline by operation

	Median	Std Error	95% CI	
			Lower	Upper
Total Hip Replacement	2.0	.338	1.3	2.7
Total Knee Replacement	5.5	.	.	.
Overall	2.8	.781	1.3	4.4

The Kaplan Meier curve (Fig.3) shows the difference in patient recovery between THR and TKR surgery.

FIGURE 3: KAPLAN MEIER CURVE TIME TO RETURN TO BASELINE BY OPERATION



The Log Rank test showed that the difference between these curves was statistically significant (p<0.034).

For the THR group, the median time for the return to pre-operative baseline value was 2.0 weeks. For the TKR group, this time was reached by 5.5 weeks.

Survival analysis by gender

Of the 22 patients, 2 out of 11 males (18.2%) and 5 out of 12 females (45.5%) failed to return to baseline (Table 3).

TABLE 3: RETURN TO BASELINE SURVIVAL ANALYSIS BY GENDER

Sex	N	N returned to baseline	Failed to return to baseline	
			N	Percent
Male	11	9	2	18.2%
Female	11	6	5	45.5%
Overall	22	15	7	31.8%

Males had a slower return to baseline (Table 4), but the proportion of females who did not reach baseline by six weeks was much higher.

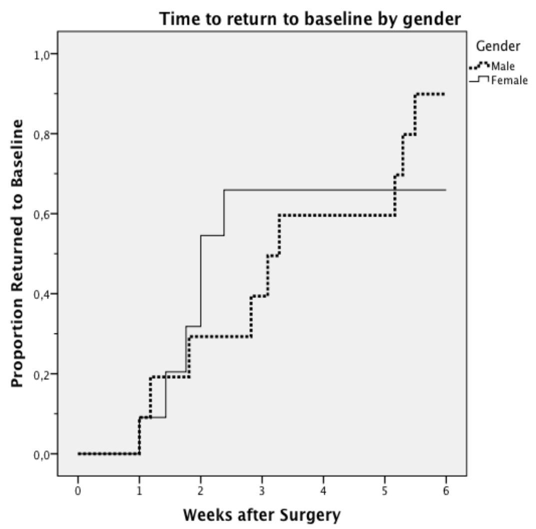
For males, the median time for the return to baseline was 3.3 weeks compared to a median time of 2.0 weeks for females.

TABLE 4: MEDIAN TIME TO RETURN TO BASELINE BY GENDER

	Median	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	3.3	.354	2.6	4.0
Female	2.0	.303	1.4	2.6
Overall	2.8	.781	1.3	4.4

The Kaplan Meier curve (fig. 4) shows the difference in recovery between males and females.

FIGURE 4: TIME TO RETURN TO BASELINE BY GENDER



The Log Rank test showed that the difference between these curves was not statistically significant (p<0.72)

Analysis of Baseline measurements

Fifteen eligible controls (without hip or knee pathology) were identified for the baseline comparison arm of the study. Seven controls (2 males and 5 females) agreed to participate.

The control group was younger than the patient groups, with an average age of 57.8 years.

Influence of Gender on patient baseline performance

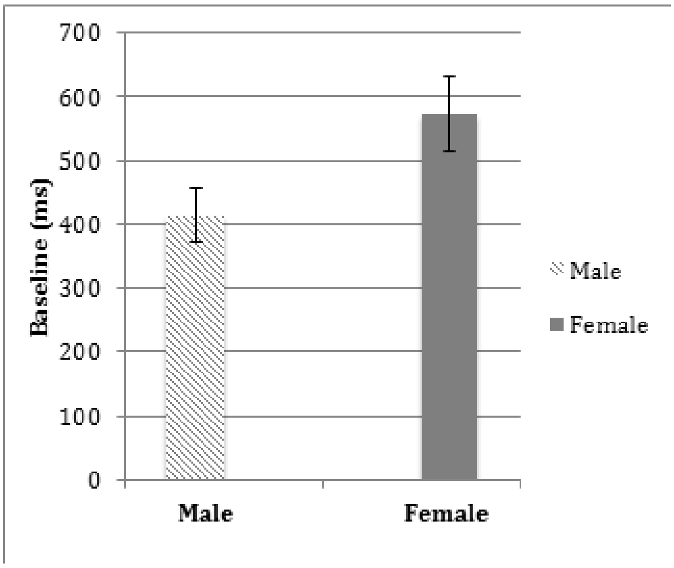
Baseline measurements of all 37 participants (30 patients and 7 controls) were compared using the one-way ANOVA test.

There were 16 male and 21 female participants who entered the study, which recorded baseline measurements. The average mean for males was 414 ms (95% CI 324-504) and higher for females at 573 ms (95% CI 450-695). The average across all participants was 504 ms (95% CI 423-585). (Table 5 and Fig. 5)

Table 5: Mean Baseline Transfer Time by Gender

	N	Mean Transfer Time	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Male	16	414	169	42.4	3234	504.	185	838
Female	21	573	269	58.7	450	695.	258	1280
Total	37	504	242	39.8	423	585	185	1280

FIGURE 5: MALE AND FEMALE PATIENT BASELINE TRANSFER TIMES



ANOVA test showed that the observed difference between the two genders was statistically significant (p<0.046).

Influence of osteoarthritis on baseline performance

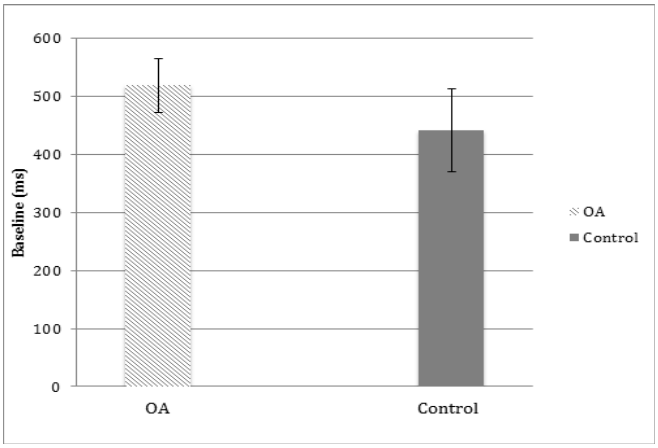
Participants from the THR and TKR groups were combined into a group termed "Advanced Arthritis" and compared to normal controls.

The 30 patients with advanced osteoarthritis recorded a mean transfer time of 519 ms (95% CI 424-613) compared to the 7 controls who had a quicker mean transfer time of 442ms (95% CI 267-616) (Table 6 and Fig.6)

TABLE 6: MEAN BASELINE TRANSFER TIME FOR PATIENTS VERSUS CONTROLS

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum
					Lower Bound	Upper Bound	
Advanced Arthritis	30	519	253	46.2	424	613	185
Control	7	442	188	71.2	267	616	258
Total	37	504	242	39.8	423	585	185

FIGURE 6: BASELINE TRANSFER TIMES PATIENTS VERSUS CONTROLS



The one-way ANOVA analysis showed that the differences between baseline transfer time in the advanced arthritis group and the control group was not statistically significant ($p<0.455$)

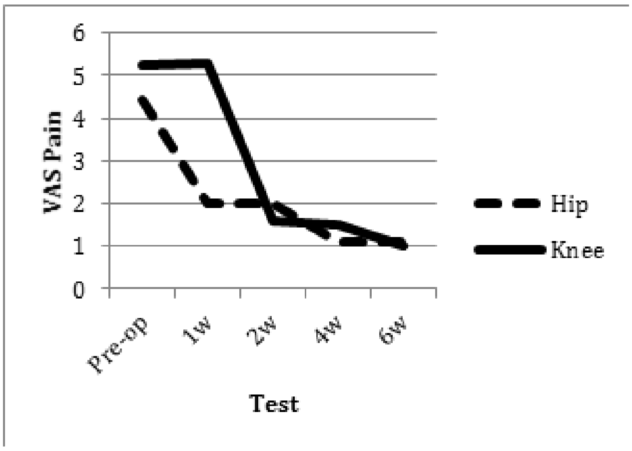
Questionnaire

Visual Analogue Score of Joint Pain

The average VAS pain score (pre-operatively) at baseline was 4.55 (95% CI 2.527-6.523). This gradually decreased until the score leveled out at 4 weeks and 6 weeks at 1.2 and 1.07 (95% CI 0.79-1.61 and 0.81-1.33).

When stratifying by operation type, patients with knee OA had a higher average VAS pain score (5.22) compared to their hip OA counterparts (4.42) at baseline, and this remained so until week 2 (Fig. 7)

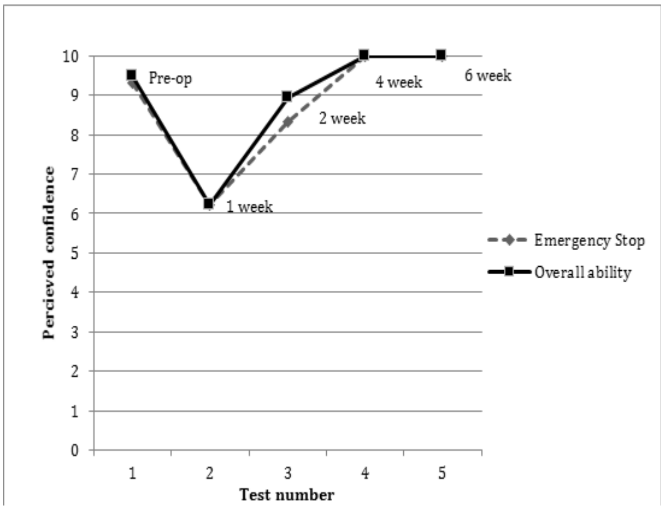
FIGURE 7: PAIN PROGRESSION BY OPERATION



Driving Confidence

Pre-operative perceived driving confidence (overall 9.48) dropped significantly by one week, but the score had recovered close to baseline (8.93). From week four onwards, all patients felt fully confident performing an emergency stop (Fig. 8).

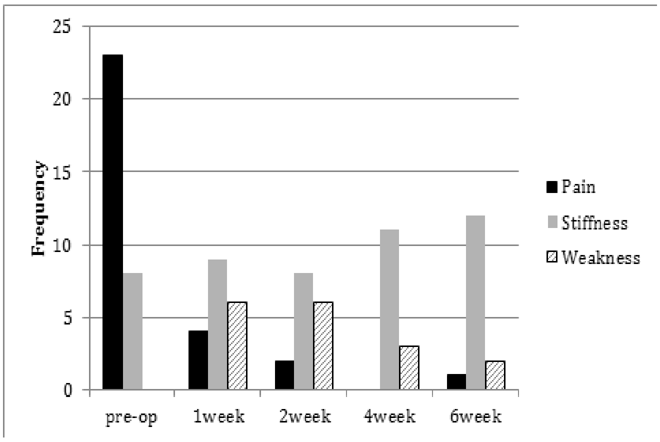
FIGURE 8: DRIVING CONFIDENCE



Most troublesome symptom

Pre-operatively the most commonly reported symptom was pain. This dropped dramatically following surgery, but stiffness remained a significant symptom right out to the six-week mark. Weakness gradually dropped to a low level at six weeks (Fig. 9)

FIGURE 9 : PROPORTION OF MOST TROUBLESOME SYMPTOMS



DISCUSSION

One of the significant findings of this study was that hip replacements recovered significantly quicker than knee replacements in returning to a safe baseline transfer time. This confirms the findings of previous research in this area.

The results from the survival analysis showed that the median baseline recovery time for THR patients was 2 weeks following surgery, and 14.3% failed to reach their baseline by 6 weeks.

TKR's median baseline recovery time was slower at 5.5 weeks, and 62.5% did not reach their baseline by 6 weeks.

By using a qualitative assessment, we were able to determine the reasons behind this difference.

Patients with knee osteoarthritis experienced more pain at baseline and in the early post-operative period (up to 2 weeks) compared to those with hip osteoarthritis.

Analysis of the post-operative symptoms revealed that pre-operative pain was a primary issue for patients but quickly dropped post-operatively. In addition, muscle weakness was a problem early on in the recovery period but dropped between weeks 4 and 6. However, post-operative joint stiffness remained an issue for patients throughout the follow-up period.

Patients were very confident in their driving ability pre-operatively, but this dropped in the first week following surgery and quickly recovered. However, this did not correlate with their physical ability.

We found that males had significantly quicker transfer times at baseline than females. However, this difference did not confer quicker recovery times.

Patients had slower baseline times than controls, but this did not reach statistical significance.

Our findings suggest that the current recommendations for returning to driving following hip replacement surgery are on the conservative side. We have observed a significantly faster recovery following THR surgery than previous research has suggested. MacDonald et al. [1] concluded that most patients were safe to drive by eight weeks, but a small number were not ready until 12 weeks. They used the same measurement of 100N brake pedal force used in this study, and they considered that patients were safe to resume driving when they had achieved a reaction time below 700ms (British Highway Code). We based our safe driving assessment on recovery of the pre-operative reaction time, which we believe gives a more accurate picture of safe driving recovery. If the patient is legally 'safe to drive' before surgery, returning to the same level of driving ability post-operatively would be a more relevant measurement.

The median time to reach baseline was 5.5 weeks for knee replacement surgery, but only 37.5% of TKR's reached their pre-surgery baseline. Unfortunately, we were not able to follow these patients beyond the 6-week mark. We had a high dropout rate in the TKR group which could explain this result. However, our findings are comparable to previous work done on TKR's. The only study to include 100N in their measured variable was Spalding et al. [7], who concluded that eight weeks of recovery time was required. Other researchers who did not include brake pedal force reported faster recovery times between 4-6 weeks [8,9].

This reflects the difficult recovery faced by patients following TKR, especially in the first post-operative week. In addition, our VAS data shows a significant difference in pain scores pre and post-operatively, which could explain the higher dropout rate in TKRs. However, the difference in return to driving ability between the two groups doesn't seem to be related to pain as both groups report similar pain at two weeks. Therefore we assume that other factors must be responsible.

All patients reported significant post-operative stiffness, which persisted up to week 6, and this would certainly have been more pronounced in the TKR group.

The survival curve shows clearly how the two groups diverged in their return to baseline. The THR group began to diverge by the first testing point and did not converge again. Although the TKR data lacks in numbers, the observed difference in performance was statistically significant ($p<0.034$)

There are many possible reasons why TKR patients perform more flawed in the braking maneuver. But, first, let's consider the mechanics of operating the brake pedal. There are essentially two elements required to do this successfully: the person has to lift and transfer the right leg and to push down forcefully on the brake.

Several different muscles will control this movement. Theoretically, one must engage the hip flexor muscles to lift the leg and transfer it from the accelerator to the brake pedal. These muscles can be affected in THR surgery, although most hip replacements are inserted through a lateral or a posterior approach sparing the hip flexor muscles. An interesting point to note is that some patients were using a pivoting movement using the rotational movement of the foot on a flexed knee joint. This movement spares the hip joint, and the rotation occurs at the ankle. This technique possibly allowed them to perform faster transfers.

To push forcefully on the brake pedal, the patient must extend the knee and plantarflex the ankle. There is no question that the quadriceps muscle is significantly weakened following knee replacement surgery [12] and the hamstrings and calf muscles. During braking, quadriceps and hamstring contraction must stabilize the knee joint in flexion and calf contraction is required to plantarflex the ankle. This is crucial to the patient's ability to perform the braking procedure, and any weakness of these muscles will affect the TKR patient's test performance. TKR patients did not seem to have any significant issues with transfer speed, but they took longer to achieve the 100N minimum required braking force. As the strength of the muscles around the knee is not affected following THR surgery, THR patients achieved the 100N force much earlier than their knee replacement counterparts.

In addition to the difference in pain, we believe this is the critical reason why these two groups of patients performed differently when the post-operative brake reaction time was measured.

CONCLUSION

We have shown that THR patients significantly outperformed TKR patients when it comes to returning safe driving ability and that there is a wide variation of recovery speed amongst patients. Therefore we recommend that patients refrain from driving for 2-4 weeks following a hip replacement and 6-8 weeks following a knee replacement.

In reality, patients' ability to drive cannot be distilled down to a simple test or a single figure. Instead, the ability to drive requires a multitude of physiological, mechanical, and psychological skills. Therefore, a doctor can give the best evidence-based advice possible but it is the driver's responsibility to know their limits and not to put other road users at risk by resuming driving before they can operate a motor vehicle safely.

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