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Higher Activity Level Following Total Knee Arthroplasty Is Not Deleterious to Mid-Term Implant Survivorship

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ABSTRACT

Background: The impact of a patient's activity level following total knee arthroplasty (TKA) remains controversial, with some surgeons concerned about increased polyethylene wear, aseptic loosening, and revisions. The purpose of this study is to report on implant survivorship and outcomes of high activity patients compared to low activity patients after TKA.
Methods: A retrospective review identified 1611 patients (2038 knees) that underwent TKA with 5-year minimum follow-up. Patients were divided in 2 groups based on their University of California Los Angeles (UCLA) activity level: low activity (LA) (UCLA $\leq$5) and high activity (HA) (UCLA $\geq$6). Outcomes included range of motion, Knee Society scores, complications, and reoperations. Parametric survival analysis was performed to evaluate the significance of activity level on survivorship while controlling for age, gender, preoperative pain, Knee Society clinical scores, Knee Society functional scores, and body mass index (BMI).
Results: Mean follow-up was 11.4 years (range 5.1-15.9). The LA group had significantly more female patients, were older, had higher BMI, and had lower functional scores preoperatively (all with $P < .001$). The HA group had significantly higher improvements in Knee Society scores ($P < .001$) and pain postoperatively ($P < .001$). Revisions were performed in 4% of the LA group and 1.7% knees of the HA group ($P = .003$). After controlling for age, gender, preoperative pain, Knee Society clinical scores, Knee Society functional scores, and BMI, a higher postoperative activity level remained a significant factor for improved survivorship with an odds ratio of 2.4 (95% confidence interval 1.2-4.7, $P = .011$). The all-cause 12-year survivorship was 98% for the HA group and 95.3% for the LA group ($P = .003$). The aseptic 12-year survivorship was 98.4% for the HA group and 96.3% for the LA group ($P = .02$).
Conclusion: Highly active patients had increased survivorship at 5-year minimum follow-up compared to lower activity patients after TKA. Patient activity level after TKA may not need to be limited with modern implants.

Multiple factors impact the wear and survivorship of total knee arthroplasty (TKA). Aseptic failures can be related to the implant, surgical technique, and patient variables. Implant-related factors include design, manufacturing, polyethylene thickness, sterilization process, and shelf life [1–3]. Surgical factors such as alignment and fixation technique can impact survivorship [4,5]. Finally, there are patient-related factors such as age, weight, and activity level that may contribute to wear and survivorship [6–8].

Sporting activity following TKA remains a controversial topic not only in what patients are able to do, but if limitations should be put on their activity level. Patients have high expectations of physical activity after TKA [9]. Implants have become more anatomic, surgical techniques are less invasive allowing rapid recovery, and polyethylene manufacturing has improved significantly

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[10–13]. With these changes, younger more active patients are seeking arthroplasty and expect to return to a high level of activity [14]. Orthopedic surgeons would all love to see patients return to whatever activities they desire. However, this must be balanced with concerns of whether there is a negative effect of activity level on implant survivorship. The literature evaluating activity level following knee arthroplasty has shown conflicting results [7,15,16], and little has been published with more modern implants.

Less than 2 decades ago, polyethylene wear was the primary mode of failure in TKA [17]. With improvements in polyethylene manufacturing, such as highly crosslinking and antioxidant additives, wear rates have significantly improved leading to a decline in failures for isolated polyethylene wear [6,11,12,18]. With modern implants, aseptic loosening and instability are now the most common causes of aseptic failure [6,19]. However, both these failure modes can still be associated with polyethylene wear and are reported at higher rates in younger more active patients [20–23]. Furthermore, while polyethylene wear rates are declining, wear is still a concern for mid to long-term TKA survivorship [11,18].

The authors recently published a study on the impact of activity level after unicondylar knee arthroplasty (UKA) in 487 patients. At a mean follow-up of 9 years, no significant difference in survivorship was found between high and low activity patients [24]. This led the authors to wonder if this same relationship would be seen in TKA patients. With modern implants, do surgeons need to modify a patient's activity level after TKA?

The purpose of this study is to evaluate the impact of postoperative activity level on outcomes and survivorship in a large cohort of patients who underwent primary TKA. The hypothesis is that there is no difference in survivorship based on activity level.

Methods

A retrospective review was performed of the author's institutional arthroplasty registry revealing 2790 consecutive patients (3530 knees) who underwent primary TKA between 2003 and 2007 who were eligible for 5-year minimum follow-up. Patients with less than 5-year follow-up who had a revision surgery were included in the analysis. Patients without a documented postoperative University of California Los Angeles (UCLA) score [25], which our institution began administering in 2011, were excluded. This yielded a cohort of 1611 patients (2038 knees) with a postoperative UCLA activity score and 5-year minimum follow-up or revision surgery.

Postoperative UCLA activity score was used to separate patients into 2 groups. The "low activity" (LA) group had a UCLA score between 1 and 5, and the "high activity" (HA) group had a UCLA score between 6 and 10. The LA group consisted of 978 patients (1210 knees) and the HA group of 633 patients (828 knees). The number of patients in each UCLA activity level is listed in Table 1.

Patient gender, age, body mass index (BMI), UCLA activity score, and length of follow-up were recorded. Operative reports and office visit notes were reviewed. Preoperative and postoperative range of motion, Knee Society functional (KSF), clinical (KSC), and pain scores [26], complications, and revisions were analyzed.

Following surgery, patients were initially seen at 6 weeks and then annually thereafter unless complications or concerns arose. Multiple attempts were made to contact patients with less than 2-year follow-up as well as reviewing hospital records, contacting primary care physicians, and querying online death index lists and obituaries.

The 2 senior authors (K.R.B., A.V.L.) performed all surgeries with a single knee system: Vanguard complete knee system (Zimmer Biomet, Warsaw, IN). Measured resection technique with cement fixation was used in all surgeries. Direct compression molded Biomet ArCom (Zimmer Biomet) polyethylene was used in all cases. Patellar resurfacing was performed in 99.8% of surgeries.

Table 1
University of California Los Angeles Activity Scale [25] and Number of Patients and Percent in Each Category.

Level	Description	No. of Patients (%)
1	Wholly inactive, dependent on others, and cannot leave residence	25 (1.2%)
2	Mostly inactive or restricted to minimum activities of daily living	164 (8%)
3	Sometimes participates in mild activities, such as walking, limited housework, and limited shopping	352 (17.3%)
4	Regularly participates in mild activities	420 (20.6%)
5	Sometimes participates in moderate activities such as swimming or could do unlimited housework or shopping	249 (12.2%)
6	Regularly participates in moderate activities	604 (29.6%)
7	Regularly participates in active events such as bicycling	114 (5.6%)
8	Regularly participates in active events, such as golf or bowling	76 (3.7%)
9	Sometimes participates in impact sports such as jogging, tennis, skiing, acrobatics, ballet, heavy labor, or backpacking	28 (1.4%)
10	Regularly participates in impact sports	6 (0.3%)

All patients signed a general research consent, approved and monitored by an independent institutional review board (Western IRB, Puyallup, WA), which allows inclusion in retrospective reviews.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel (Microsoft Corporation, Redmond, WA) and MedCalc Statistical Software version 18.6 (MedCalc Software bvba, Ostend, Belgium). Unpaired *t*-test was used for statistical analysis of continuous variables between groups. Chi-squared and Fisher's exact test compared binary variables. Parametric survival analysis using Weibull regression model was performed to evaluate the significance of activity level on survivorship while controlling for age, gender, preoperative pain, KSC, KSF, and BMI. Kaplan-Meier survival analysis was performed with failure being defined as revision of any component.

Results

The mean follow-up of all patients was 11.4 years (range 5.1-15.9, standard deviation [SD] ±1.9 years), with the LA group follow-up averaging 11.4 years (range 5.2-15.9, SD ±2 years) and the HA group averaging 11.3 years (range 5.1-15.5, SD ±2 years) ($P = .28$). Ten-year minimum follow-up was available in 1745 knees (87%).

Table 2
Preoperative Demographics, Range of Motion, and Outcomes Between Activity Groups.

Characteristic	LA	HA	*P* Value
Number of patients	1210	828	
Number of knees	978	633	
Gender of patients			
Male patients	330 (27%)	383 (46%)	
Female patients	880 (73%)	445 (54%)	<.001
Gender of knees			
Knees in male patients	269 (28%)	292 (46%)	
Knees in female patients	709 (72%)	341 (54%)	<.001
Mean body mass index (kg/m^2)	34.6	32.8	<.001
Mean age (y)	64.9	62.3	<.001
Mean range of motion (°)	108.5	109	.42
Mean Knee Society clinical score	41.4	40.7	.31
Mean Knee Society pain score	8.2	8.6	.44
Mean Knee Society functional score	49.6	55.3	<.001

LA, low activity (University of California Los Angeles score 1-5); HA, high activity (University of California Los Angeles score 6-10).

Table 2 compares the demographics and preoperative data between groups. The LA group had significantly more female patients, were older, had higher BMI, and had lower preoperative KSF scores. Postoperative pain, range of motion, and clinical score comparison between groups are listed in Table 3. The HA group had significantly higher improvements in KSC scores, KSF scores, and pain postoperatively.

Revisions of at least one component were performed in 49 knees (4%) in the LA group and 14 (1.7%) knees in the HA group ($P = .003$). Table 4 lists the reasons for revision between groups. Aseptic failure rate was 3% in the LA group and 1.3% in the HA group ($P = .01$). The mean time to failure for all causes in the LA group was 5.3 years (range 0.2-12.7) compared to 4.6 years (range 0.2-12.2) in the HA group ($P = .58$). The mean time to failure for aseptic loosening or instability in the LA group was 6.7 years (range 0.9-12.7) compared to 5.8 years (range 1.4-12.2) in the HA group ($P = .85$). In the most active patients with a UCLA of 9 or 10 there was one revision that occurred 4.8 years after surgery. This was for a polyethylene exchange due to instability.

After performing regression analysis controlling for age, gender, preoperative pain, KSC, KSF, and BMI, a higher postoperative activity level remained a significant factor for improved survivorship. The increased survival was significant using the HA cutoff as defined in this study with a survival odds ratio of 2.4 (95% confidence interval [CI] 1.2-4.7, $P = .011$) as well as increased survivorship as UCLA activity level increased as a categorical variable (1-10) ($P = .015$).

Revision with isolated polyethylene exchange was performed in 17 knees in the LA group and 7 knees in the HA group. The remainder of revisions had the tibial and/or femoral component revised.

In patients who did not have a revision, radiographic radiolucencies and/or polyethylene wear were documented in 5 knees (0.4%) in the LA group and 7 knees (0.9%) in the HA group ($P = .23$).

Kaplan-Meier analysis revealed that the all-cause 12-year survivorship was 98% (95% CI 97.4-98.6) for the HA group and 95.3% (95% CI 94.6-96) for the LA group ($P = .003$) (Fig. 1). The aseptic 12-year survivorship was 98.4% (95% CI 97.9-98.9) for the HA group and 96.3% (95% CI 95.6-97) for the LA group ($P = .02$) (Fig. 2).

Discussion

This study found that patients with a higher activity level after TKA had significantly greater survivorship for all-cause and aseptic failures. The more active patients also had greater improvement in clinical and functional scores as well as more significant reduction in pain. There was no difference in time to failure between activity groups.

One difficulty with assessing the impact of activity level on TKA is that there is no consensus on what constitutes LA vs HA. Numerous activity scoring tools are available, often on 10 point or 100 point scales, but at what level does someone become “highly active”? In looking at the impact of activity level after partial knee arthroplasty, Ali et al [27] defined patients with HA as having a Tegner level of 5 or more. Others have used gait cycles to define activity level, with those who complete >3 million gate cycles per year or 1 hour of activity per day an HA patient [28]. In the authors' previous study looking at activity level after UKA, a UCLA score ≥7 was used to define HA [24]. That group of UKA patients was overall more active than the current TKA cohort with the majority of the patients in this study (80%) having a UCLA score between 3 and 6. Setting a UCLA cutoff of ≥6 in this study produced more evenly matched groups. To help with the arbitrary cutoff, statistical analysis was also performed with the entire spectrum of possible UCLA scores and relationship to implant survivorship.

Multiple studies have demonstrated that patient activity level improves after TKA and many patients do return to sports [16,29,30]. The question is, to what extent does a patient's activities impact the longevity of their knee replacement and how should we guide our patients' postoperative activity level? The concern about a high patient activity level after joint replacement is that increased impact and gait cycles could lead to accelerated polyethylene wear and failure [31,32]. Patients who are highly active produce about 3 times the knee cycles per year as a person with an average activity level [33]. UCLA activity has been shown to correlate well with gait cycles, and thus should be able to be used as proxy of knee cycles [34].

Polyethylene durability has significantly improved over the past decades with changes in manufacturing [11,12]. However, aseptic loosening and polyethylene wear remain the main concern for failure in younger, active patients [22,34–36]. Assessment of polyethylene wear in TKA in vivo is difficult [37]. For this reason, autopsy and retrieval studies are often used to evaluate TKA wear. Two studies have focused on the relationship of activity to wear rates in retrieved polyethylene. Lavernia et al [7] reported on 23 post-mortem retrieved TKAs and found that patients with a lower UCLA activity level had less extent and severity of polyethylene creep. This study had some limitations regarding their conclusions on activity level and wear. First, activity level was determined retrospectively based on journal entries from the surgeon and then a UCLA score was estimated. Second, only preoperative UCLA activity level, not postoperative, was significantly associated with wear. Rohrbach et al evaluated the association between activity and polyethylene wear in 49 knees from autopsy and retrieval at revision. They grouped patient's activity based on self-reported walking capacity: low (0-15 minutes), medium (15-60 minutes), and high (>60 minutes). Higher activity level was significantly associated with increased wear ($P = .025$) with an observed power of 0.689 [38]. Both of the aforementioned studies noted that time of implantation had the strongest correlation with wear, as well as both studies assessed older conventional polyethylene [7,38]. In the

Table 3
Postoperative Demographics, Range of Motion, and Outcomes Between Activity Groups.

Characteristic	LA	HA	*P* Value
Mean range of motion (°)	111.4	111.3	.28
Range of motion improvement (°)	3.8	5.2	.03
Mean Knee Society clinical score	87.1	98.9	<.001
Knee Society clinical score improvement	45.9	52.3	<.001
Mean Knee Society pain score	42.4	48.1	<.001
Knee Society pain score improvement	34.2	39.5	<.001
Mean Knee Society functional score	51.4	88.8	<.001
Knee Society functional score improvement	2.1	33.6	<.001

LA, low activity (University of California Los Angeles score 1-5); HA, high activity (University of California Los Angeles score 6-10).

Table 4
Reason for Revision Between Activity Groups.

Characteristic	LA	HA	*P* Value
Infection	13	3	.07
Aseptic loosening	4	2	.9
Fracture	5	0	.09
Instability	15	5	.15
Pain	2	1	.8
Arthrofibrosis	7	1	.1
Patellar tendon rupture	0	1	<.001
Unknown	3	0	<.001
Patellar AVN	0	1	.1
Total	49	14	.003

LA, low activity (University of California Los Angeles score 1-5); HA, high activity (University of California Los Angeles score 6-10); AVN, avascular necrosis.

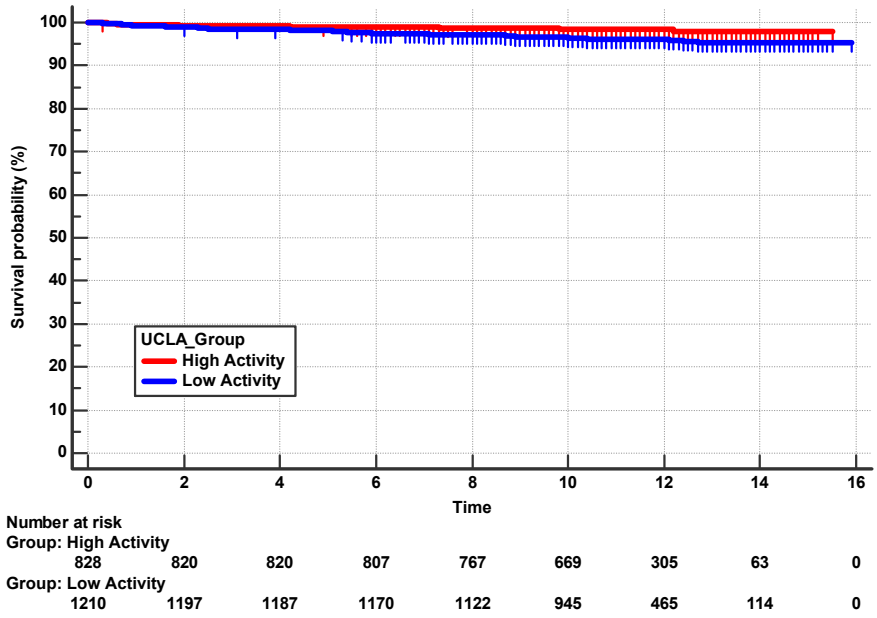

Fig. 1. Kaplan-Meier all-cause survival of low activity and high activity.

current study, the HA group had only a 0.8% incidence of revision for failure due to instability or aseptic loosening.

Other studies looking at the relationship of activity level in TKA have focused on survivorship rather than just polyethylene wear itself. Diduch et al [15] reported on 108 active patients <55 years old and found 95% survivorship at 18 years, which included 2 revisions for infection. Only 1 patient was aseptically revised. Valle et al followed patients for 12 years after TKA and compared those who continued to participate in sports to those who did not. They found that the group that continued with sports had 36% less revisions than the less active group [39]. Meftah et al [16] published on 55 TKAs in active patients <60 years old with 11-year minimum follow-up and found 98% survivorship with no revisions for osteolysis or loosening. Goh et al [40] reported 97.8% survivorship at a mean of 7 years on 136 TKAs in patients <50 years old.

Age as a risk factor for failure is more often discussed than activity level in arthroplasty literature. Younger age, though, is often extrapolated as a proxy for more active patients. In the current study, the more active patients were younger on average by 2.6 years. Schmalzried et al [41] found that after TKA, patients <60 years old averaged 5732 steps/d, whereas those >60 years old averaged 4400 steps/d. In a large registry analysis, young active patients ≤45 years -old had an 8 times higher revision rate for polyethylene wear and 3 times higher revision rate for aseptic loosening than the general population [22]. However, many other studies have shown excellent survivorship of >95% in younger patients undergoing TKA with modern implant designs [15,16,40,42,43]. Younger patients are at the highest risk for lifetime revision by virtue of the fact that they will live longer with their implant. For this reason, it is important to carefully evaluate literature noting the association between younger

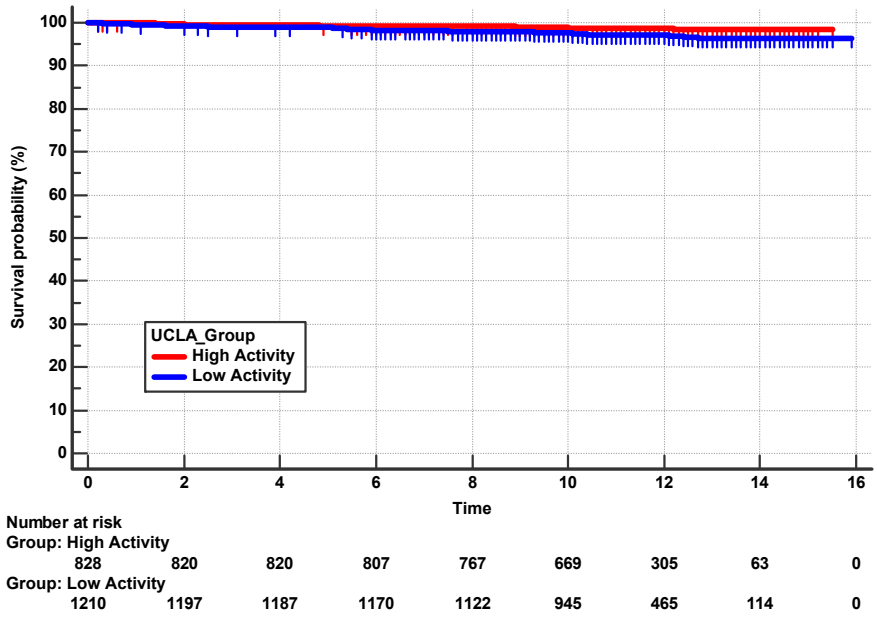

Fig. 2. Kaplan-Meier aseptic survival of low activity and high activity.

age and survivorship. The current study found no significant difference in time to failure between the HA and LA groups at a mean of 11.4 years of follow-up.

An inherent limitation in this study assessing postoperative activity level with TKA survivorship is determination of cause and effect. For example, patients who have a painful or failing TKA are likely going to be less active. Furthermore, some patients just are not very active even though their knee could tolerate more activity. Likewise, some patients remain active despite a painful or failing joint. Correlation, rather than causation, can only be concluded. It is unclear to the authors why a higher activity level would improve implant survivorship. These more active patients may just have a better functioning knee. More importantly for patients though is that a higher level of activity was not deleterious to implant longevity. Another limitation of this study is that radiographic assessments were based on clinic note documentation and not individually reviewed for this study. No radiographic measurements were made to assess polyethylene wear and patients may have had more evidence of radiolucencies than were documented in the notes. Finally, 42% of eligible patients were not included in this study due to lack of follow-up and/or no documented UCLA activity score. The strength of this study is that, to the authors' knowledge, it represents the largest cohort of comparative activity levels on TKA survivorship along with 87% of patients having 10-year minimum follow-up. Differences in preoperative demographics and activity level were able to be controlled to show that higher activity level alone was still a significant predictor of increased survival.

In conclusion, this study demonstrated that patients with a higher activity level following TKA had a lower incidence of failure at a mean of 11.4-years of follow-up. Furthermore, no significant differences were found in time to failure between LA and HA patients. Patient activity level many not need to be limited following TKA with modern implants.

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