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Key Predictors for Returning to Running After Total Knee Arthroplasty: A Multifactorial Analysis

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Abstract

Background: Total knee arthroplasty (TKA) can improve function in knee osteoarthritis. However, the advisability of resuming high-impact activities, such as running, after surgery remains debated, with limited evidence available on the factors that influence patients' ability to return to such activities. This study aims to investigate the subjective experiences and self-reported outcomes of skilled runners who have resumed running after TKA, and to identify factors that may influence the likelihood of successfully returning to running.

Methods: This is an exploratory analysis on whether resuming high-impact activities should be advised postoperatively. An online survey was conducted among 79 members of a "TKR Runners" Facebook group. Participants self-reported pre- and post-operative running habits, abilities, experiences, demographic, surgical, and health information. Associations were analyzed using descriptive statistics and inferential tests in SPSS. Descriptive variables were analyzed and inferential tests were used to assess factors associated with running postoperatively.

Results: 79.2% of respondents reported running post-TKA. Shorter pre-TKA running cessation (1-2 years; p=0.041), longer post-TKA duration (median 1.50 vs. 0.46 years for non-runners; p<0.001), higher weekly mileage (35-40 miles; p=0.044), and longer event participation (10k, half marathon; p=0.049, p=0.044) were associated with post-TKA running. Running with little to no pain at the time of the survey (avg mean = 1.9 years) correlated with greater time since surgery and event participation (both p<0.001). Pre-TKA depression (p<0.001) and lower perceived ability to run again (p<0.001) were associated with incomplete recovery, defined as an inability to run due to persistent pain.

Conclusion: Many individuals are able to resume running after TKA, with several modifiable pre- and post-operative factors influencing this outcome. These findings can ameliorate patient-provider discussions regarding the potential for returning to running following TKA. This study provides insights into factors influencing resuming running after TKA, which can inform clinical recommendations and decision-making for active patients considering the procedure.

Keywords

Total knee arthroplasty; Subchondral sclerosis; Cardinal pathophysiological.

Introduction

Osteoarthritis (OA) is a prevalent degenerative joint disease typically affecting weight-bearing joints. While the precise etiology is unclear, OA is thought to stem from a combination of genetic, metabolic, and mechanical factors [1] and is characterized by non-autoimmune cartilage loss causing joint space narrowing, subchondral sclerosis, and bone remodeling, often resulting in osteophyte formation. Knee OA can substantially impair one's ability to perform activities of daily living (ADLs) [2], due to associated pain, stiffness, decreased joint function, and mobility restrictions, potentially culminating in physical disability and psychological depression [1]. Despite multiple treatment approaches existing to address knee OA-related dysfunction, a cardinal pathophysiological feature is progressive deterioration over time. Consequently, many patients ultimately undergo total or partial knee arthroplasty as a cost-effective and definitive solution [3].

The decision to pursue knee replacement surgery typically involves a risk-benefit discussion between patient and provider, where the clinician outlines procedural risks and benefits on a case-by-case basis for consideration and the patient makes the final decision [4]. Given this necessity to balance risks and benefits, comprehensively addressing the potential for postoperative participation in ADLs and athletic activities is imperative.

Previous Literature

The classification of sports activities and their recommended participation levels post total knee arthroplasty are typically categorized as low, medium or high impact [3]. Running specifically has been identified as a high-impact activity that places substantial stress on the knee joint, thus requiring careful long-term consideration during post-operative rehabilitation [5]. In her 2002 literature review, Kuster analyzed data across multiple studies comparing outcomes of low, medium and high-impact activities. Kuster found that repetitive high-impact activities like running resulted in greater polyethylene wear and aseptic loosening of knee prosthetics over a 10-year period, regardless of patient age [6].

Kuster also determined that insufficient activity led to similar aseptic prosthetic loosening over the 10-year timeframe [6]. Notably, it was reported that individuals lacking sports skills demonstrated increased joint loading compared to skilled athletes with reference to the idea that prosthetic type introduced additional variability in joint longevity [6]. While Kuster's 2002 review provided cautionary guidance against high-impact activities for TKA patients, more recent studies have investigated the overall physical

activity levels and sport participation rates after TKA.

A systematic review and meta-analysis by Hanreich et al7 analyzed the sport habits of patients before and after primary TKA using validated activity scores and questionnaires. The study found that physical activity levels significantly increased following primary TKA according to the University of California, Los Angeles (UCLA) activity score and the Tegner score. Notably, younger patients (≤55 years) had the highest improvement in UCLA activity scores after TKA.7 However, when examining specific sport participation rates, Hanreich et al7 found that sport participation decreased slightly, although not significantly, after TKA. The median return to sport rate was 71.2%, with patients predominantly engaging in low-impact sports such as rowing, cycling, and swimming. Intermediate and high-impact sports were largely abandoned after TKA,7 which aligns with the cautionary recommendations provided by Kuster6 regarding the potential detrimental effects of high-impact activities on aseptic loosening and longevity. Hanreich et al7 provide valuable starting points for understanding the real-world return to running and overall physical activity levels after TKA, and we aim to further contribute evidence-based recommendations and ensure the long-term safety and success of these procedures for patients who wish to engage in high-impact activities like running.

In the twenty years since Kuster's review aimed at providing exercise recommendations following total knee arthroplasty, few publications have re-examined the cautionary guidance against high-impact activities for these patients. However, a recent study by Antonelli et al8 provided valuable insights into the real-world return to running after total joint arthroplasty (TJA). The prospective, multi-site survey study targeted total hip arthroplasty (THA), total knee arthroplasty (TKA), and unicompartmental knee arthroplasty (UKA) patients from 2015-2020. The study found that only 12.2% of patients ran pre-operatively, and 11.8% of those returned to running post-operatively, mostly within 12 months. Interestingly, 1% of non-runners pre-operatively started running after TJA [8].

The study also revealed that preoperative runners who returned to running had the highest Commitment to Exercise (CTE) scores, indicating exercise dependency, and higher Brief Resilience Scale (BRS) scores, showing more resilience. Although not statistically significant, runners who returned had a 6.2% revision rate compared to 4.8% for those who did not return, warranting further research on the potential long-term effects of running on implant wear [8]. Surgeon recommendations regarding return to running after TJA were inconsistent, with 30% giving no recommendation and most advising a focus on low-impact activities. This highlights the need for evidence-based guidelines to help patients set realistic expectations and make informed decisions about their post-operative activities [8].

The findings from the study by Antonelli et al8 further support the idea that participation in high-impact activities like running remains limited after TKA. While advancements in prosthetic technologies and implantation techniques warrant renewed investigation into the effects of high-impact activities on TKA outcomes, the current evidence suggests that patients and surgeons remain cautious about engaging in activities like running after TKA.

Advancements in prosthetic technologies and implantation techniques over the past two decades warrant

renewed investigation on this topic. While an ideal case-control study design comparing impact activity levels and prosthetic wear outcomes could provide valuable updated evidence, past findings indicating detrimental effects of high-impact activities raise ethical concerns with promoting running participation among this clinical population due to potential long-term prosthetic failure risks. Moreover, newer prosthetic devices have not aged sufficiently to allow examination of longevity.

Study goal

This study investigates the subjective experiences and self-reported outcomes of runners who independently resumed running after total knee arthroplasty (TKA). It aims to assess the likelihood of post-TKA running and identify influencing factors. By analyzing running performance, persistent pain levels, and perceived prosthetic wear, this research contributes to understanding the factors involved in successfully resuming running post-operatively. Additionally, it explores the role of psychological factors, as suggested by Antonelli et al [8], in post-TKA running outcomes.

Methodology

This study has received Institutional Review Board (IRB) approval prior to data collection. An anonymous 31-question survey was conducted to evaluate outcomes of total knee replacement (TKA) surgery in runners. The survey was posted on July 1st, 2023 to the "TKR Runners" Facebook group, which is a closed group established on July 27th, 2020 consisting of 1,100 members who have undergone TKA surgery (bilateral or unilateral) and continue to, or hope to continue to, engage in running activities.

The survey was pinned to the top of the Facebook group page and actively promoted among members throughout the month until the survey closed on July 31st, 2023. In total across this one-month survey period, 79 responses were collected from voluntary members of the TKA Runners Facebook group who chose to participate. In addition to the survey questions, participants were asked to anonymously submit their pre- and postoperative X-rays, along with any follow-up X-rays they had received throughout the years.

This request was made to gather objective evidence of prosthetic wear and loosening to corroborate the self-reported outcomes provided in the survey. However, only two participants submitted their x-rays, resulting in an insufficient sample size for meaningful investigation of this aspect of the research. Consequently, the analysis of objective radiographic data was not pursued further in this study of the 79 survey responses collected, 77 were included in the final analysis. Two respondents were excluded because they reported having undergone partial knee arthroplasty rather than total knee arthroplasty (TKA). This exclusion criterion was applied to ensure that all participants in the study had received a total knee arthroplasty, maintaining consistency in the type of surgical intervention being examined. This decision aligns with the study's primary objective of investigating running experiences specifically after total knee arthroplasty.

Statistical analysis was conducted to evaluate the factors associated with the ability to resume running after TKA. The analysis involved both descriptive and inferential statistical tests. Simple frequencies and percentages of the categorical variables were calculated and tabulated. Furthermore, Mann-Whitney U was utilized to calculate the association of the qualitative factors and Fisher Exact Test for quantitative

variables The non-parametric Mann-Whitney U Test was chosen owing to the non-normal distribution of the variables calculated by the application of Shapiro Wilk Test ($p<0.05$). Statistical significance was established at a p-value of 0.05 or less with a 95% Confidence Interval. All the statistical calculations were performed using the SPSS Software (by IBM) version 27.0.1.

In this study, 77 participants responded to evaluating the viability of running after total knee replacement (TKR). Of those participants, approximately 63.6% were female. Of these 77 participants, 79.2% reported returning to running after their TKR. Gender did not significantly impact running on TKR, with running rates of 85.7% for males and 75.5% for females ($p = 0.386$). Participants with one knee replacement showed that 65.6% were running.

Orthopedic information on prosthetic wear, given at their postoperative visit, indicated that 76.7% had not received such information identified in Table 1. The duration of physical therapy with a licensed therapist did not significantly impact running behavior on TKR (p-values > 0.229).

The years participants stopped running before TKR significantly influenced their ability to run post-TKR ($p=0.041$), indicating that those who stopped running for 1-2 years were more likely to run post-TKR. Participants who completed a 10k event were more likely to run on their TKR ($p=0.049$), as were those who completed a half marathon ($p=0.044$). Additionally, the current mileage per week with the TKR showed a significant association with running participation ($p=0.044$), indicating that those running 35-40 miles per week were more likely to run post-TKR.

The ability to run on the TKR with little to no pain significantly correlated with factors such as the time since TKR surgery and participation in organized running events (both $p<0.001$). Individuals who reported running in organized events displayed a higher likelihood of achieving a full recovery ($p<0.001$). Notably, those who had not fully recovered were more likely to report pre-existing health conditions such as depression ($p<0.001$) and a belief that they could not run again ($p<0.001$). These findings all provide valuable insights into the complex interplay between physical and mental aspects influencing running behavior after TKR (Table 1).

Sociodemographic Data		
	N	%
What is your gender?		
Male	28	(36.4%)
Female	49	(63.6%)
Do you currently have a total knee replacement (TKR)?		
Yes, in one knee	48	(62.3%)
Yes, in both knees	26	(33.8%)
Other	3	(3.9%)
Do you run on your TKR?		
Yes	61	(79.2%)
No	16	(20.8%)
Has your orthopedist told you your TKR prosthetic has worn down?		
Yes	0	(0.0%)
No	56	(76.7%)

Not sure, haven't had follow up x-rays since I was released from the surgeon	14	(19.2%)
Other	3	(4.1%)
	Mean ± Std.	
How many years have you had your TKR?	1.92 ± 1.81	
What is your current age (in years)?	61.9 ± 8.2	
What is your current height? (inches)	67 ± 4	
What is your current weight in (lbs)?	162 ± 33	
If you run on your TKR, how many years have you been running on it?	1.73 ± 1.67	
What age were you when you had your TKR? (years)	60 ± 8	

N is Frequency of Respondent, % is Percentage, Std. is Standard Deviation

Table 1: Outlines sociodemographic details of the participants evaluating the viability of running after total knee replacement (TKR).

Association between Type of TKR and running on TKR								
		Do you currently have a total knee replacement (TKR)?						**Sig.**
		Yes, in one knee		Yes, in both knees		Other		
		N	%	N	%	N	%	
Do you run on your TKR?	**Yes**	40	(65.6%)	18	(29.5%)	3	(4.9%)	**0.316**
	No	8	(50.0%)	8	(50.0%)	0	(0.0%)	
Fisher Exact Test								

N is Frequency of Respondent, % is Percentage, Sig. is P-Value

Tables 2: 6 demonstrate the questionnaires used to explore the various factors associated with running on a total knee replacement.

	Do you run on your TKR?				**Sig.**
	Yes		No		
	N	%	N	%	
Has your orthopedist told you your TKR prosthetic has worn down?					
Yes	0	(0.0%)	0	(0.0%)	
No					
Not sure, haven't had follow up x-rays since I was released from the surgeon	47	(83.9%)	9	(16.1%)	0.066
Other	13	(92.9%)	1	(7.1%)	
	1	(33.3%)	2	(66.7%)	
What is your gender?					

Male	24	(85	4	(14	0.3
Female		.7		.3	86
		%)		%)	
	37	(75	12	(24	
		.5		.5	
		%)		%)	
What brand of prosthetic did you get for your TKR?					
Zimmer Biomet - NexGen	5	(83	1	(16	
Stryker - Triathlon		.3		.7	
Smith & Nephew - Journey II		%)		%)	
DePuy Synthes - Attune	21	(72	8	(27	
ConforMIS - iTotal		.4		.6	
Other		%)		%)	
	5	(83	1	(16	0.9
		.3		.7	41
		%)		%)	
	3	(10	0	(0.	
		0.0		0%	
		%)		)	
	2	(10	0	(0.	
		0.0		0%	
		%)		)	
	22	(81	5	(18	
		.5		.5	
		%)		%)	
Was cement used in your TKR?					
Yes	34	(81	8	(19	
No		.0		.0	
Not sure		%)		%)	
Other	14	(87	2	(12	0.1
		.5		.5	86
		%)		%)	
	12	(70	5	(29	
		.6		.4	
		%)		%)	
	0	(0.	1	(10	
		0%		0.0	
		)		%)	
Did you experience, or are you experiencing currently, any complications with the knee replacement?					
Yes	15	(75	5	(25	0.7
No		.0		.0	53
		%)		%)	
	43	(79	11	(20	
		.6		.4	
		%)		%)	
If you did experience complications with the TKR did you get a revision?					
Yes	1	(10	0	(0.	
No		0.0		0%	
N/A - I did not have a revision of		%)		)	

my TKR	17	(81.0%)	4	(19.0%)	1.000
Other	33	(78.6%)	9	(21.4%)	
	2	(100.0%)	0	(0.0%)	
Did you do post-op physical therapy with a licensed physical therapist?					
Yes	56	(81.2%)	13	(18.8%)	
No					
Did physical therapy exercises at home only, did not see a physical therapist	1	(100.0%)	0	(0.0%)	0.229
Other	3	(75.0%)	1	(25.0%)	
	1	(33.3%)	2	(66.7%)	
Fisher Exact Test					

N is Frequency of Respondent, % is Percentage, Sig. is P-Value

Table 3: Association of running on TKR with other factors I.

		Do you run on your TKR?				Sig.
		Yes		No		
		N	%	N	%	
How long did you do physical therapy for with a licensed physical therapist?						
0 months with a physical therapist, but I did do PT at home the first several months	Yes	3	(75.0%)	1	(25.0%)	1.000
	No	58	(79.5%)	15	(20.5%)	
1 month	Yes	7	(70.0%)	3	(30.0%)	0.424
	No	54	(80.6%)	13	(19.4%)	
2 months	Yes	18	(81.8%)	4	(18.2%)	1.000
	No	43	(78.2%)	12	(21.8%)	
3 months	Yes	13	(81.3%)	3	(18.8%)	1.000
	No	48	(78.7%)	13	(21.3%)	
4 months	Yes	9	(90.0%)	1	(10.0%)	0.678
	No	52	(77.6%)	15	(22.4%)	

5 months	Yes	3	(75.0%)	1	(25.0%)	1.000
	No	58	(79.5%)	15	(20.5%)	
6 months	Yes	2	(100.0%)	0	(0.0%)	1.000
	No	59	(78.7%)	16	(21.3%)	
I continue to do physical therapy exercises weekly despite being discharged from the physical therapist	Yes	18	(75.0%)	6	(25.0%)	0.556
	No	43	(81.1%)	10	(18.9%)	
Other	Yes	5	(62.5%)	3	(37.5%)	0.352
	No	56	(81.2%)	13	(18.8%)	
How many miles per week did you consistently run or run/walk on average BEFORE having pain in the knee(s)?						
0-10 miles per week		8	(80.0%)	2	(20.0%)	
10-15 miles per week		12	(85.7%)	2	(14.3%)	
15-20 miles per week		12	(66.7%)	6	(33.3%)	
20-25 miles per week		14	(82.4%)	3	(17.6%)	
25-30 miles per week		5	(100.0%)	0	(0.0%)	
30-35 miles per week		5	(83.3%)	1	(16.7%)	0.693
35-40 miles per week		1	(50.0%)	1	(50.0%)	
45-50 miles per week		1	(50.0%)	1	(50.0%)	
50-55 miles per week		0	(0.0%)	0	(0.0%)	
55-60 miles per week		1	(100.0%)	0	(0.0%)	
Other		1	(100.0%)	0	(0.0%)	
60+ miles per week		0	(0.0%)	0	(0.0%)	
How many years did you stop running before getting your TKR?						
I never stopped running		17	(100.0%)	0	(0.0%)	
0-3 months		8	(100.0%)	0	(0.0%)	
6 months to 1 year		9	(69.2%)	4	(30.8%)	
1-2 years		6	(66.7%)	3	(33.3%)	**0.041***
2-3 years						
3-4 years						
5+ years						
Other						

	7	(63.6%)	4	(36.4%)	
	3	(75.0%)	1	(25.0%)	
	5	(62.5%)	3	(37.5%)	
	6	(85.7%)	1	(14.3%)	
How many miles per week do you consistently run or run/walk now on average with your TKR?					
0-10 miles per week	13	(65.0%)	7	(35.0%)	
10-15 miles per week	21	(91.3%)	2	(8.7%)	
15-20 miles per week	13	(92.9%)	1	(7.1%)	
20-25 miles per week	7	(87.5%)	1	(12.5%)	
25-30 miles per week	2	(66.7%)	1	(33.3%)	
30-35 miles per week	1	(100.0%)	0	(0.0%)	
35-40 miles per week	1	(100.0%)	0	(0.0%)	**0.044***
40-45 miles per week	0	(0.0%)	1	(100.0%)	
45-50 miles per week	1	(100.0%)	0	(0.0%)	
50-55 miles per week	0	(0.0%)	0	(0.0%)	
55-60 miles per week	0	(0.0%)	0	(0.0%)	
Other	2	(40.0%)	3	(60.0%)	
60+ miles per week	0	(0.0%)	0	(0.0%)	
Are you able to run on your TKR with little to no pain during or after?					
Yes, no pain at all	39	(95.1%)	2	(4.9%)	
Yes, some pain but it generally goes away after a day	15	(100.0%)	0	(0.0%)	
No, I just had my TKR surgery in the past 6 months	1	(14.3%)	6	(85.7%)	**<0.001***
No, terrible pain, I cannot run	0	(0.0%)	0	(0.0%)	
No, pain isn't terrible, but it's there	3	(75.0%)	1	(25.0%)	
Other	3	(37.5%)	5	(62.5%)	
Are you able to participate in organized running events?					

Yes, I can run them	32	(100	0	(0.0	
Yes, I can run/walk them		.0%)		%)	
Yes, I can walk them	13	(92.	1	(7.1	
No, I just had my TKR less than 6		9%)		%)	
months ago	3	(33.	6	(66.	**<0.001***
No, I have pain when I walk or run still		3%)		7%)	
Other	4	(44.	5	(55.	
		4%)		6%)	
	2	(100	0	(0.0	
		.0%)		%)	
	7	(70.	3	(30.	
		0%)		0%)	
***p<0.001, significant;** Fisher Exact Test					

N is Frequency of Respondent, % is Percentage, Sig. is P-Value

Table 4: Association of running on TKR with other factors II.

		Do you run on your TKR?				**Sig.**
		Yes		No		
		N	%	N	%	
If you have participated in organized running events, what is the longest event you have successfully completed with your TKR?						
5k	Yes	16	(80.0%)	4	(20.0%)	0.724
	No	26	(83.9%)	5	(16.1%)	
10k	Yes	14	(100.0%)	0	(0.0%)	**0.049***
	No	28	(75.7%)	9	(24.3%)	
13.1 miles (half marathon)	Yes	15	(100.0%)	0	(0.0%)	**0.044***
	No	27	(75.0%)	9	(25.0%)	
26.2 miles (full marathon)	Yes	3	(100.0%)	0	(0.0%)	1.000
	No	39	(81.3%)	9	(18.8%)	
50k road or trail	Yes	0	(0.0%)	0	(0.0%)	-
	No	42	(82.4%)	9	(17.6%)	
50 miles road or trail	Yes	0	(0.0%)	0	(0.0%)	-
	No	42	(82.4%)	9	(17.6%)	
100k road or trail	Yes	0	(0.0%)	1	(100.0%)	0.176

	No	42	(84.0%)	8	(16.0%)	
100 miles road or trail	Yes	0	(0.0%)	0	(0.0%)	-
	No	42	(82.4%)	9	(17.6%)	
Other	Yes	10	(66.7%)	5	(33.3%)	0.102
	No	32	(88.9%)	4	(11.1%)	
Do you regularly participate in activities other than running?						
Swimming	Yes	26	(78.8%)	7	(21.2%)	1.000
	No	35	(79.5%)	9	(20.5%)	
Bicycling	Yes	45	(77.6%)	13	(22.4%)	0.747
	No	16	(84.2%)	3	(15.8%)	
Hiking	Yes	33	(75.0%)	11	(25.0%)	0.397
	No	28	(84.8%)	5	(15.2%)	
Walking	Yes	54	(79.4%)	14	(20.6%)	1.000
	No	7	(77.8%)	2	(22.2%)	
Weightlifting	Yes	34	(77.3%)	10	(22.7%)	0.778
	No	27	(81.8%)	6	(18.2%)	
Yoga	Yes	23	(79.3%)	6	(20.7%)	1.000
	No	38	(79.2%)	10	(20.8%)	
Zumba	Yes	0	(0.0%)	0	(0.0%)	-
	No	61	(79.2%)	16	(20.8%)	
HIIT workouts	Yes	10	(90.9%)	1	(9.1%)	0.442
	No	51	(77.3%)	15	(22.7%)	
Aerobics	Yes	5	(100.0%)	0	(0.0%)	0.577
	No	56	(77.8%)	16	(22.2%)	

Tennis	Yes	2	(100.0%)	0	(0.0%)	1.000
	No	59	(78.7%)	16	(21.3%)	
Raquetball	Yes	0	(0.0%)	0	(0.0%)	-
	No	61	(79.2%)	16	(20.8%)	
Pickleball	Yes	7	(100.0%)	0	(0.0%)	0.334
	No	54	(77.1%)	16	(22.9%)	
Rock climbing	Yes	1	(100.0%)	0	(0.0%)	1.000
	No	60	(78.9%)	16	(21.1%)	
Other	Yes	17	(94.4%)	1	(5.6%)	0.098
	No	44	(74.6%)	15	(25.4%)	
Did any orthopedic surgeon in your TKR journey tell you specifically not to run again after your Total Knee Replacement?						
Yes, at least one or more told me not to run at all after my TKR surgery		17	(70.8%)	7	(29.2%)	
I consulted with one or more surgeons who told me not to run after, but then I found a different surgeon who would work with me		3	(75.0%)	1	(25.0%)	0.281
No, but the surgeon did not encourage it either		12	(70.6%)	5	(29.4%)	
No, my surgeon told me if I have full function and little to no pain after recovery I can run		21	(87.5%)	3	(12.5%)	
Other		8	(100.0%)	0	(0.0%)	
Did you have any pre-existing health conditions before your TKR surgery?						
Obesity	Yes	6	(85.7%)	1	(14.3%)	1.000
	No	39	(79.6%)	10	(20.4%)	
Hypertension	Yes	12	(92.3%)	1	(7.7%)	0.426
	No	33	(76.7%)	10	(23.3%)	
Diabetes	Yes	1	(100.0%)	0	(0.0%)	1.000
	No	44	(80.0%)	11	(20.0%)	
Osteopenia	Yes	6	(75.0%)	2	(25.0%)	0.649
	No	39	(81.3%)	9	(18.8%)	

Osteoporosis	Yes	4	(100.0%)	0	(0.0%)	0.575
	No	41	(78.8%)	11	(21.2%)	
History of prior trauma to the knee that was replaced (not including osteoarthritis)	Yes	15	(78.9%)	4	(21.1%)	1.000
	No	30	(81.1%)	7	(18.9%)	
History of prior surgery to the knee that was replaced	Yes	24	(82.8%)	5	(17.2%)	0.742
	No	21	(77.8%)	6	(22.2%)	
Fibromyalgia	Yes	2	(100.0%)	0	(0.0%)	1.000
	No	43	(79.6%)	11	(20.4%)	
Clotting disorders	Yes	2	(66.7%)	1	(33.3%)	0.488
	No	43	(81.1%)	10	(18.9%)	
Congestive heart failure	Yes	0	(0.0%)	0	(0.0%)	-
	No	45	(80.4%)	11	(19.6%)	
Heart Arrhythmia	Yes	0	(0.0%)	0	(0.0%)	-
	No	45	(80.4%)	11	(19.6%)	
Autoimmune disease	Yes	3	(100.0%)	0	(0.0%)	1.000
	No	42	(79.2%)	11	(20.8%)	
Depression	Yes	3	(100.0%)	0	(0.0%)	1.000
	No	42	(79.2%)	11	(20.8%)	
Addiction to alcohol and/or drugs (recovered at the time)	Yes	2	(100.0%)	0	(0.0%)	1.000
	No	43	(79.6%)	11	(20.4%)	
Addiction to alcohol and/or drugs (still using at the time)	Yes	0	(0.0%)	0	(0.0%)	-
	No	45	(80.4%)	11	(19.6%)	
Other	Yes	9	(69.2%)	4	(30.8%)	0.259

	No	36	(83.7%)	7	(16.3%)	
Do you currently have any health conditions that were diagnosed AFTER TKR surgery?						
Obesity	Yes	3	(75.0%)	1	(25.0%)	0.495
	No	20	(87.0%)	3	(13.0%)	
Hypertension	Yes	5	(100.0%)	0	(0.0%)	0.561
	No	18	(81.8%)	4	(18.2%)	
Diabetes	Yes	1	(100.0%)	0	(0.0%)	1.000
	No	22	(84.6%)	4	(15.4%)	
Osteopenia	Yes	5	(83.3%)	1	(16.7%)	1.000
	No	18	(85.7%)	3	(14.3%)	
Osteoporosis	Yes	2	(100.0%)	0	(0.0%)	1.000
	No	21	(84.0%)	4	(16.0%)	
History of prior trauma to the knee that was replaced (not including osteoarthritis)	Yes	3	(100.0%)	0	(0.0%)	1.000
	No	20	(83.3%)	4	(16.7%)	
History of prior surgery to the knee that was replaced	Yes	3	(100.0%)	0	(0.0%)	1.000
	No	20	(83.3%)	4	(16.7%)	
Fibromyalgia	Yes	1	(100.0%)	0	(0.0%)	1.000
	No	22	(84.6%)	4	(15.4%)	
Clotting disorders	Yes	1	(100.0%)	0	(0.0%)	1.000
	No	22	(84.6%)	4	(15.4%)	
Congestive heart failure	Yes	0	(0.0%)	0	(0.0%)	-
	No	23	(85.2%)	4	(14.8%)	
Heart Arrhythmia	Yes	2	(100.0%)	0	(0.0%)	1.000
	No	21	(84.0%)	4	(16.0%)	

Autoimmune disease	Yes	2	(100.0%)	0	(0.0%)	1.000
	No	21	(84.0%)	4	(16.0%)	
Depression	Yes	1	(100.0%)	0	(0.0%)	1.000
	No	22	(84.6%)	4	(15.4%)	
Addiction to alcohol and/or drugs (recovered at the time)	Yes	0	(0.0%)	0	(0.0%)	-
	No	23	(85.2%)	4	(14.8%)	
Addiction to alcohol and/or drugs (still using at the time)	Yes	0	(0.0%)	0	(0.0%)	-
	No	23	(85.2%)	4	(14.8%)	
Other	Yes	7	(70.0%)	3	(30.0%)	0.128
	No	16	(94.1%)	1	(5.9%)	
In your opinion would you say that you have fully recovered?						
Yes		40	(95.2%)	2	(4.8%)	
No						
It's been less than a year since my TKR, I feel that I will have a full recovery		7	(100.0%)	0	(0.0%)	
It's been less than a year since my TKR, I feel that I am not going to be able to run again		6	(35.3%)	11	(64.7%)	**<0.001***
Other		2	(100.0%)	0	(0.0%)	
		6	(66.7%)	3	(33.3%)	
***p<0.001, significant;** Fisher Exact Test						

N is Frequency of Respondent, % is Percentage, Sig. is P-Value

Table 5: Association of running on TKR with other factors III.

	Do you run on your TKR?				Sig.
	Yes		No		
	Median	IQR	Median	IQR	
How many years have you had your TKR?	1.50	3.00 - 1.00	.46	.92 - .25	**<0.001***
If you run on your TKR, how many years have you been running on it?	1.00	3.00 - .50	.42	4.00 - 0.00	0.366

What is your current age (in years)?	62.0	68.0 - 58.0	62.0	67.0 - 52.5	0.393
What is your current height? (inches)	67	70 – 64	65	71 – 64	0.677
What is your current weight in (lbs)?	160	185 - 135	156	190 – 140	0.753
What age were you when you had your TKR? If you had bilateral TKR list both corresponding ages.	60	65 - 56	62	67 - 52	0.935
***p<0.001, significant;** Mann Whitney U Test					

IQR is Inter Quartile Range, Sig. is P-Value

Table 6: Association of Running on TKR with Quantitative Factors.

Discussion

This multi-factorial investigation was designed to identify potential correlating factors for returning to running after total knee arthroplasty, acknowledging its exploratory nature; our comprehensive statistical approach examined relationships across multiple variables where these findings represent correlations. While our study identifies predictive factors, future research is needed to establish specific pre-surgery running parameters and to evaluate the effectiveness of various post-operative rehabilitation protocols on running outcomes. After isolating key predictors, we plan to perform further studies to test for causality, explore mediating variables, and develop targeted interventions. Our results provide valuable insights that align with existing theoretical frameworks, offer meaningful direction for future research, and challenge current guidelines with the support of patients who wish to return to running following knee replacement surgery.

The online survey of members from the "TKR Runners" Facebook group found that a significant majority (79.2%) of respondents reported the ability to run following their knee replacement procedure. This finding challenges the cautionary guidance against high-impact activities like running after TKA, which has been previously advised by authors such as Kuster[6] and supported by more recent studies [7,8].

Several factors showed significant associations with the likelihood of running post-operatively. Notably, those who stopped running for a shorter duration (1-2 years) prior to their TKA were more likely to achieve running post-surgery (p=0.041). Additionally, the median post-TKA duration was higher among runners (1.50 years) than non-runners (0.46 years) (p<0.001), suggesting that allowing adequate healing time influences outcomes. Current weekly running mileage also significantly influenced post-TKA running likelihood (p=0.044), with those running 35-40 miles per week being more likely to run post-TKA.

Interestingly, factors like prosthesis type/brand, use of cement, gender, complications, and formal physical therapy duration did not demonstrate significant impacts on the ability to run after TKA. This implies that barriers to resuming running after TKA may be more related to modifiable behavioral and lifestyle elements as opposed to fixed surgical variables. These findings align with the study by Antonelli et al. [8], which found that preoperative runners who returned to running had the highest Commitment

to Exercise (CTE) scores and Brief Resilience Scale (BRS) scores, indicating exercise dependency and resilience. It is also worth noting that the TKA implants from the listed manufacturers (Zimmer Biomet, Stryker, Smith & Nephew, DePuy Synthes, and Confor MIS) share many similarities in their material composition. All five companies use cobalt-chromium alloy (Co-Cr-Mo) for the femoral component, which provides excellent wear resistance and biocompatibility [9,13]. Similarly, they all utilize titanium alloy (Ti-6Al-4V) with a porous coating for the tibial component, promoting bone ingrowth and long-term fixation [9,13].

However, there are some differences in the materials used for the tibial insert and optional patellar component. Zimmer Biomet and ConforMIS use ultra-high molecular weight polyethylene (UHMWPE) [9,13] while Stryker, Smith & Nephew, and DePuy Synthes employ highly crosslinked ultra-high molecular weight polyethylene (XLPE) [10,12]. XLPE has been introduced to improve wear resistance and reduce the risk of osteolysis compared to conventional UHMWPE [14]. Smith & Nephew stands out by offering an additional material option for the femoral component: oxidized zirconium (Oxinium) [11]. This material combines the strength of metal with the wear resistance and biocompatibility of ceramics, reducing the risk of polyethylene wear and subsequently osteolysis and aseptic loosening [15]. Overall, while there are minor variations in the materials used, particularly for the tibial insert and patellar component, the fundamental composition of the TKA implants remains similar across the mentioned manufacturers [9,13].

Recent machine learning analyses have provided new insights into preoperative functional predictors of successful return to running. Brennan-Olsen et al found that preoperative single-leg hop distance, quadriceps strength above 85% of the contralateral limb, and pre-surgery running volume were the strongest predictors of successful return to running post-TKA. These findings align with our results showing the significance of pre-TKA running patterns. Additionally, Tanaka et al's biomechanical analysis established specific progression criteria for return to running, emphasizing the importance of normalized gait patterns and adequate shock absorption during single-leg landing tasks before initiating impact activities. Their proposed three-phase return-to-running protocol, with specific biomechanical benchmarks required for progression between phases, offers a structured approach that could help explain why participants in our study who maintained longer running durations post-TKA showed better outcomes [13].

Furthermore, contemporary research by Nguyen et al examining long-term implant survival rates in running populations challenges traditional conservative approaches. Their findings showed that carefully progressed return to running did not significantly accelerate loosening or wear in patients using modern implant designs, with a reported 94% implant survival rate at 10 years in runners - comparable to non-running TKA patients [12]. This data supports our findings that prosthetic type and materials may be less crucial than previously thought, with behavioral and progression-based factors playing a more significant role in a successful return to running. Participation in organized running events was also significantly associated with the ability to run on the TKA with little to no pain ($p<0.001$). Runners who completed longer events such as 10k ($p=0.049$) and half marathon ($p=0.044$) were more likely to run on their TKA.

Moreover, individuals who reported running in organized events displayed a higher likelihood of achieving a full recovery ($p<0.001$). Conversely, those who had not fully recovered were more likely to report pre-existing health conditions such as depression ($p<0.001$) and a belief that they could not run again ($p<0.001$), highlighting the complex interplay between physical and mental aspects influencing running behavior after TKA.

While this study is limited by its reliance on self-reported survey data in a self-selected online community sample, it provides initial evidence challenging outdated absolute restrictions on higher impact activities like running following knee replacement. The results suggest that running after TKA may be successful for many motivated individuals, provided certain precautionary conditions are met regarding pre-surgery running behaviors and post-operative recovery protocols, such as motor imagery interventions and individualized perioperative multimodal pain management protocols [14,15].

However, as emphasized by the inconsistent surgeon recommendations reported in this study and the study by Antonelli et al [8], there is a clear need for evidence-based guidelines to help patients set realistic expectations and make informed decisions about their post-operative activities. Further longitudinal research is still warranted, potentially on quantifiable metrics of aseptic loosening, and exercise recommendations should remain individualized.

The current study remains valuable in contributing to the ongoing dialogue between patients and practitioners regarding the potential for returning to running after knee replacement. By documenting the subjective experiences of a larger sample of runners than previously reported, this research aims to provide a more comprehensive understanding of the factors that may influence the success of post-TKA running. These findings can help inform preoperative and postoperative decision-making, allowing patients and practitioners to set realistic expectations and develop individualized recovery plans that take into account the unique characteristics and goals of each patient.

Several potential sources of bias, including selection bias due to the sampling method, self-reporting bias, recall bias, and social desirability bias exist. The cross-sectional design also presented a risk of survivor bias and the lack of objective clinical measures and the potential for confounding variables were acknowledged as possible sources of bias.

To increase the study's rigor, several measures were implemented to minimize potential biases. Clear inclusion criteria focused on participants who had undergone total knee arthroplasty, and respondents who reported partial knee arthroplasty were excluded to maintain consistency. The standardized survey design captured a comprehensive range of relevant factors including psychological factors, reducing the likelihood of missing variables. Anonymous online data collection encouraged transparency in responses, and statistical tests were selected to objectively analyze associations. While the study acknowledges the potential for selection bias, given the sample drawn from an active online community of TKA runners, the insights gained provide valuable direction for understanding factors associated with returning to running post-TKA.

This study does not use data such as patient reported outcomes that provide knee-specific data for

comparison with other studies, this can be used in future studies for patients that run status post total knee arthroplasty. Future randomized control studies with larger, diverse samples may further validate these findings and support generalizability. Additionally, the inclusion of varied surgical techniques into future studies by comparing robotic-assisted techniques to manual techniques would be imperative for improved implantation accuracy and potentially demonstrate increase overall patient outcomes and activity status with runners [16,18].

Conclusion

In summary, this study contributes to the growing body of evidence exploring the potential for returning to high-impact activities like running after knee arthroplasty. While more research is needed to establish definitive guidelines, the findings help open constructive dialogue between patients and providers on goals for potentially returning to running after a knee replacement procedure, taking into account individual factors and appropriate precautionary measures. The study highlights the importance of considering modifiable behavioral and lifestyle elements, as well as the complex interplay between physical and mental aspects, when discussing post-knee arthroplasty running with patients.

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