ANDREI MACHADO VIEGAS DA TRINDADE

AVALIAÇÃO E EVOLUÇÃO DA MARCHA, MOBILIDADE FUNCIONAL E QUALIDADE DE VIDA DOS PACIENTES SUBMETIDOS A ARTROPLASTIA DO JOELHO: UM ESTUDO LONGITUDINAL

Tese apresentada ao Curso de Pós-Graduação da Faculdade de Ciências Médicas da Santa Casa de São Paulo para obtenção do Título de **Doutor** em **Ciências da Saúde.**

SÃO PAULO 2026

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Área de Concentração: **Ciências da Saúde**
Orientadora: Prof.ª Dra. Claudia Santos Oliveira

Coorientador: Prof. Dr. Claudio Santilli

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1. Artroplastia do joelho 2. Prótese e implantes 3. Análise da marcha 4. Teste de caminhada

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DEDICATÓRIA

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“What is not measured cannot be improved.”

(O que não é medido não pode ser melhorado.)

Lord Kelvin

LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

OA	Osteoartrose
ATJ	Artroplastia total de joelho
TKA	Total knee arthroplasty / artroplastia total de joelho
TKR	Total knee replacement / artroplastia total de joelho
FB	Prótese de platô fixo pósteroestabilizada
MB	Prótese de platô móvel ultracongruente
CR	Posterior cruciate retaining / retenção do ligamento cruzado posterior
PS	Posterior stabilized / Póstero-estabilizado
IMC	Índice de massa corporal
TCLE	Termo de consentimento livre e esclarescido
CEP	Comitê de Ética em Pesquisa
CONEP	Comissão Nacional de Ética em Pesquisa
WOMAC	Western Ontario McMaster Universities Osteoarthritis Index
GLFS-10P	Geriatric Locomotive Function Scale - 10 items Portuguese
GLFS-25	Geriatric Locomotive Function Scale - 25 items
TUG	Timed Up and Go Test
2MWT	2-Minute Walk Test / Teste de Caminhada de 2 Minutos
6MWT	6-Minute Walk Test / Teste de Caminhada de 6 Minutos
10MWT	10-minute Walt Test / Teste de Caminhada de 10 Minutos
IMU	Inertial Measurement Unit / Unidade de Medida Inercial
G-Walk®	Sensor inercial portátil BTS Bioengineering
ICC	Intraclass Correlation Coefficients / Coeficientes de Correlação Intraclasse
ANOVA	Analysis of Variance / Análise de Variância
DMCI	Diferença Mínima Clinicamente Importante
PROMS	Patient-Reported Outcome Measures / Medidas de Desfecho Relatadas pelo Paciente

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PREFÁCIO

O trabalho de pesquisa aqui desenvolvido e intitulado ***Avaliação e evolução da marcha, mobilidade funcional e qualidade de vida dos pacientes submetidos a artroplastia do joelho: um estudo longitudinal***. Este estudo prospectivo e longitudinal foi desenvolvido no programa de Doutorado da Faculdade de Ciências Médicas da Santa Casa de São Paulo, na área de concentração de Ciências da Saúde sob orientação da Profª. Drª. Claudia Santos Oliveira e coorientação do Prof. Dr. Claudio Santilli. O Programa de Doutorado em Ciências da Saúde da Faculdade de Ciências Médicas da Santa Casa de São Paulo permite a inclusão, no corpo do exemplar da tese, de artigos publicados, aceitos ou submetidos para publicação em seu formato de publicação ou submissão. A seção 1 apresenta uma contextualização sobre a osteoartrose do joelho, abordando seus principais aspectos epidemiológicos e clínicos, a artroplastia total do joelho como tratamento cirúrgico, a evolução dos desenhos de próteses de joelho e a importância da avaliação objetiva no período pós-operatório. Além disso, discute o uso de sensores inerciais na avaliação da marcha após a cirurgia e apresenta a justificativa e a relevância do estudo proposto. Os objetivos gerais e específicos, assim como a hipótese da pesquisa são apresentados na seção 2, e todos os procedimentos metodológicos são apresentados na seção 3. A seção 4 são apresentados os resultados de toda a pesquisa. A seção 5 apresenta a discussão dos resultados com a literatura. As considerações finais e as referências bibliográficas são apresentadas nos tópicos 5 e 6, respectivamentePor fim, todos os anexos são apresentados no tópico 7: Aprovação CEP/CONEP – UniEvangélica, Renovação aprovação CEP/CONEP – UniEvangélica, Declaração de Instituição Coparticipante, Termo de Consentimento Livre e Esclarecido (TCLE), Ficha de Coleta de Dados Clínicos e Demográficos, Questionário WOMAC Versão Português (Western Ontario McMaster Universities Index), Escala GLFS-10P Versão curta em Português (short version of the 25-question Geriatric Locomotive Function Scale-Portuguese) e os artigos na íntegra os artigos publicados no periódico **Journal of *Advances in Medicine and Medical Research*** *– Qualis Capes A3, ISSN 2456-8899: Use of Sensors in Rehabilitation of Patients Undergoing Knee Arthroplasty: A Systematic Review* (doi.org/10.9734/jammr/2025/v37i126031); *Functional Performance Tests Following Unilateral Total Knee Arthroplasty: Protocol for a Scoping Review* (doi.org/10.9734/jammr/2025/v37i126020); *Functional Mobility Assessment after Unilateral Knee Arthroplasty: A Comparative Study of Two Prosthesis Types* (doi.org/10.9734/jammr/2025/v37i15695); *Biomechanical Assessment of Patients with Unilateral Total Knee Arthroplasty: A Preliminary Comparative Study* (doi.org/10.9734/jammr/2025/v37i15696); no periódico **Life** – Qualis Capes A2 ISSN 2075-1729: Instrumented Functional Mobility Assessment in Elderly Patients Following Total Knee Arthroplasty: A Retrospective Longitudinal Study Using the Timed Up and Go Test (doi.org/10.3390/life15091409). Na mesma seção são apresentados os artigos submetidos e revisão: no periódico **Journal of Arthroplasty** – Qualis Capes A1 ISSN 1532-8406: *Spatiotemporal gait parameters and functional performance following total kneearthroplasty: A longitudinal comparison of fixed-bearing versus mobile-bearing prostheses*; no periódico **Journal of Personalized Medicine** – Qualis Capes A1 ISSN 2075-4426: *Spatiotemporal Gait Parameters in Fixed versus Rotating Bearing Total Knee Arthroplasty: A Prospective 24-Month Longitudinal Study* (preprint doi.org/10.20944/preprints202601.0196.v1) e no periódico: Symmetry – Qualis Capes A4 2073-8994: *Impact of Massive Weight Loss Following Bariatric Surgery on 2 Gait Mechanics After Total Knee Arthroplasty: A Case Report* (preprint doi.org/10.20944/preprints202601.0265.v1) e o resumo expandido publicado no periódico: Gait and Posture – Qualis Capes A2 ISSN 0966-6362: *Longitudinal*

Evaluation of Functional Mobility in Different Knee Prostheses Using an Inertial Sensor

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SUMÁRIO

1. INTRODUÇÃO

1.1 A Osteoartrose do Joelho: Aspectos Epidemiológicos e Clínicos

A osteoartrose (OA) do joelho é uma doença articular degenerativa crônica caracterizada por alterações estruturais progressivas da cartilagem articular, do osso subcondral e das estruturas periarticulares, incluindo músculos, ligamentos, sinóvia e tecido adiposo (Silverwood et al., 2015; Primorac et al., 2020; Kloppenburg et al., 2025). Esta condição musculoesquelética progressiva apresenta elevada prevalência global, acometendo indivíduos de diferentes faixas etárias, porém com aumento exponencial da incidência e prevalência após os 65 anos. Constitui a forma mais comum de artrite entre adultos e representa uma das principais causas de incapacidade funcional em países desenvolvidos e em desenvolvimento (Hartvigsen et al., 2018; Kloppenburg et al., 2025).

A patogênese da osteoartrose do joelho envolve mecanismos biomecânicos complexos, alterações estruturais progressivas, processos inflamatórios sistêmicos e fatores genéticos. O processo inflamatório desempenha papel significativo na etiologia e progressão da doença, caracterizando-se pela presença de mediadores inflamatórios no líquido sinovial que induzem enzimas proteolíticas associadas à ação de leucócitos, resultando em lesão cartilaginosa secundária à destruição progressiva do colágeno articular (Mora et al., 2018; Sharma, 2021; Katz et al., 2021). Embora a relação causa-efeito entre inflamação e degradação cartilaginosa não esteja completamente elucidada, evidências crescentes sugerem que a inflamação funciona tanto como causa quanto como consequência dos processos degenerativos articulares (Mora et al., 2018; Molnar et al., 2021).

As causas da osteoartrose do joelho frequentemente relacionam-se a alterações mecânicas com aumento das forças físicas causadoras de danos articulares, alterações anatômicas congênitas ou adquiridas, excesso de carga (aguda ou crônica), ou a combinações multifatoriais destas etiologias (Felson et al., 2013; Doung et al., 2025). Os fatores de risco principais incluem idade avançada, sexo feminino, sobrepeso e obesidade, histórico de lesões articulares prévias e predisposição genética (Silverwood et al., 2015; Doung et al., 2025).

O impacto clínico e epidemiológico da osteoartrose do joelho é substancial. De acordo com estimativas do Global Burden of Disease 2016, a osteoartrose foi responsável por aproximadamente 9,6% dos anos vividos com incapacidade em nível global (Global Burden of Disease Collaborative Network, 2017). No Brasil, aproximadamente 25 milhões de indivíduos apresentam sintomas de osteoartrose, representando cerca de 12% da população total (Zhao et al., 2019; Carregaro et al., 2020). Os custos econômicos associados ao tratamento da osteoartrose do joelho são consideráveis, incluindo despesas diretas com assistência médica, procedimentos cirúrgicos, reabilitação, além de custos indiretos relacionados à perda de produtividade laboral e impacto significativo na qualidade de vida dos pacientes acometidos (Carregaro et al., 2020; Jin et al., 2023).

1.2 A Artroplastia Total do Joelho como Tratamento Cirúrgico

A artroplastia total do joelho é o tratamento cirúrgico de escolha para pacientes com osteoartrose avançada (classificação de Kellgren-Lawrence $\geq$ 3-4) que não apresentam resposta adequada às modalidades de tratamento conservador, incluindo terapia farmacológica, reabilitação fisioterapêutica e modificação de atividades (Argenson et al., 2013; Price et al., 2018; Benedetto et al., 2019). O procedimento cirúrgico objetiva restaurar a função articular, aliviar a dor crônica, corrigir deformidades angulares e, fundamentalmente, melhorar a qualidade de vida relacionada à saúde dos pacientes (Benedetto et al., 2019; Ferrini et al., 2025).

Apesar do sucesso técnico em termos de alinhamento mecânico, estabilidade ligamentar e manutenção adequada da amplitude de movimento, uma parcela significativa de pacientes submetidos a artroplastia total do joelho permanece insatisfeita com os resultados funcionais no período pós-operatório. Estudos prospectivos demonstram que a taxa de insatisfação pós-operatória varia entre 15% a 30% dos pacientes operados, dependendo dos critérios de satisfação utilizados e das características demográficas da população estudada (Hamilton et al., 2015; Scott et al., 2016; Gunaratne et al., 2017; Ashoorion et al., 2023). Estes pacientes frequentemente relatam persistência de dor residual, limitação funcional inadequada ou melhora insuficiente da qualidade de vida quando comparada com as expectativas pré-operatórias.

A compreensão aprofundada dos fatores que influenciam os resultados funcionais e a satisfação pós-operatória é essencial para otimizar os cuidados perioperatórios, aperfeiçoar as técnicas cirúrgicas e estabelecer seleção mais apropriada de desenhos de implantes. Diversos fatores têm sido investigados como potenciais preditores de resultados inadequados, incluindo variáveis demográficas (idade avançada, sexo), características pré-operatórias (amplitude de movimento limitada, força muscular deficiente), comorbidades sistêmicas e fatores psicossociais (Hamilton et al., 2015; Astephen et al., 2016; Scott et al., 2016).

1.3 Evolução dos Desenhos de Próteses de Joelho

A evolução contínua e progressiva dos materiais e desenhos de próteses de joelho reflete avanços significativos na engenharia biomédica, na compreensão de mecanismos de falha dos implantes e na avaliação crítica de resultados clínicos de longo prazo (Insall et al., 1989; Lewis et al., 2020; Olson et al., 2025). Os desenhos de próteses contemporâneos evoluíram dramaticamente desde o desenvolvimento das primeiras próteses articulares viáveis nas décadas de 1970 e 1980, passando por múltiplas gerações de aperfeiçoamento tecnológico.

As próteses contemporâneas podem ser classificadas em diferentes categorias de acordo com mecanismos de estabilidade ligamentar e design construtivo: (1) próteses condilares que retêm ambos os ligamentos cruzados (Posterior Cruciate Retaining - CR); (2) próteses póstero-estabilizadas que realizam sacrifício do ligamento cruzado posterior e sua substituição através do desenho geométrico específico do implante (Posterior Stabilized - PS); e (3) próteses ultracongruentes com platô tibial móvel que combinam características de estabilidade intrínseca com graus de liberdade articular preservados (Fuller et al., 2021; Zimnoch et al., 2025). O desenho da interface tibial evoluiu significativamente, particularmente com a introdução de platôs móveis que permitem maior liberdade de movimento na articulação tibial e redução das forças de cisalhamento nas interfaces implantares.

Estudos biomecânicos e clínicos sugerem que o tipo de implante utilizado pode influenciar significativamente os resultados funcionais pós-operatórios, incluindo parâmetros de marcha, mobilidade funcional, satisfação do paciente e potencialmente a longevidade do implante (Hamilton et al., 2015; Mandeville et al., 2007; Kowalski et al., 2025). As próteses com platô móvel ultracongruente oferecem potencial teórico para: (1) melhor acomodação aos padrões naturais de marcha individual dos pacientes; (2) redução das forças de desgaste e cisalhamento no implante, potencialmente incrementando a longevidade clínica; (3) restauração mais fidedigna da cinemática articular fisiológica; e (4) possibilidade de maior satisfação funcional, particularmente em pacientes com demandas funcionais elevadas ou idade avançada (De Vroey et al., 2018; Canovas & Dagnneaux, 2018; Kowalski et al., 2025).

1.4 A Importância da Avaliação Objetiva Pós-Operatória

A avaliação adequada e abrangente dos resultados funcionais após artroplastia total do joelho requer uma abordagem multifatorial que integre medidas objetivas e subjetivas de múltiplas dimensões do resultado. As avaliações subjetivas, incluindo questionários de satisfação do paciente, escalas de qualidade de vida relacionada à saúde e autoavaliação de capacidade funcional, fornecem perspectiva clínica importante sobre a percepção individual do paciente quanto aos resultados obtidos e seu impacto na vida cotidiana (Ritter et al., 2003; Canovas & Dagnneaux, 2018).

No entanto, estas medidas baseadas em percepção do paciente podem não capturar completamente o estado funcional objetivo ou os padrões de movimento reais apresentados pelos indivíduos (Graff et al., 2016; Biggs et al., 2019; Misu et al., 2022). Parâmetros biomecânicos objetivos, tais como análise quantitativa da marcha, mobilidade funcional mensurada através de testes de desempenho padronizados e análise de simetria de movimento entre membros inferiores, fornecem dados mensuráveis, reproduzíveis e biologicamente significativos sobre a recuperação funcional real e a restauração da capacidade locomotora (Mandeville et al., 2007; Bugané et al., 2012; Galli et al., 2015; Boekesteijn et al., 2022; Misu et al., 2022).

Estudos anteriores que compararam medidas objetivas e subjetivas em pacientes submetidos a artroplastia total do joelho demonstraram correlações fracas a moderadas entre estas dimensões de avaliação (Graff et al., 2016; Biggs et al., 2019). Esta observação sugere que medidas objetivas e subjetivas capturam aspectos distintos e complementares do resultado clínico, evidenciando que ambas são necessárias para alcançar compreensão abrangente e acurada do resultado funcional real (Mandeville et al., 2007; Graff et al., 2016; Biggs et al., 2019; Boekesteijn et al., 2022).

1.5 Sensores Inerciais na Avaliação da Marcha Pós-Operatória

Avanços tecnológicos recentes em sistemas de sensoriamento inercial portátil permitiram a avaliação objetiva, confiável e clinicamente prática de parâmetros quantitativos de marcha em ambientes ambulatoriais, eliminando a necessidade de laboratórios sofisticados e custosos de análise de movimento convencional (Bugané et al., 2012; Pau et al., 2015; De Vroey et al., 2018). Os sensores inerciais integram acelerômetros tri-axiais e giroscópios tri-axiais que possibilitam quantificação precisa de parâmetros espaço-temporais da marcha, características de balanço corporal e índices de simetria de movimento entre membros inferiores.

Estudos de validação de sensores inerciais portáteis em populações diversas, incluindo indivíduos saudáveis e aqueles com condições neuromusculoesqueléticas, demonstraram que parâmetros de marcha obtidos através desta tecnologia apresentam correlação significativa com medidas de análise de marcha laboratorial tridimensional, considerada padrão-ouro (Bugané et al., 2012; Pau et al., 2015; Youn et al., 2020). Além disso, parâmetros de marcha quantificados por sensores inerciais apresentam correlação significativa com achados de testes de desempenho funcional e questionários padronizados de qualidade de vida em pacientes submetidos a artroplastia unilateral de joelho (De Vroey et al., 2018; Youn et al., 2020).

As vantagens práticas da utilização de sensores inerciais em avaliações clínicas são substanciais. O tempo necessário para coleta de dados com sensores inerciais é minimal, geralmente entre 10-15 minutos, reduzindo significativamente custos operacionais e permitindo avaliações seriadas em ambiente de atenção ambulatorial sem necessidade de agendamento em laboratórios especializados (Bugané et al., 2012; Pau et al., 2015; De Vroey et al., 2018). Adicionalmente, sensores inerciais portáteis permitem quantificação objetiva de assimetrias persistentes de marcha que podem permanecer mesmo após satisfação subjetiva do paciente com os resultados da cirurgia, oferecendo perspectiva adicional sobre o status funcional real (De Vroey et al., 2018; Youn et al., 2020).

1.6 Justificativa e Relevância do Estudo

Considerando a prevalência crescente de artroplastia total do joelho na população envelhecida, a necessidade cientificamente fundamentada de melhorar os resultados funcionais pós-operatórios e a evolução contínua dos desenhos de implantes disponíveis no mercado, existe lacuna importante no conhecimento a respeito das diferenças funcionais objetivas entre diferentes tipos de implantes utilizando metodologia padronizada, instrumentos validados e seguimento longitudinal prospectivo (Argenson et al., 2013; Hamilton et al., 2015; Benedetto et al., 2019; Irmola et al., 2025).

Estudos prévios que compararam diferentes desenhos de prótese de joelho foram frequentemente limitados por delineamento transversal, avaliação em momento único pós-operatório, utilização de instrumentos de avaliação subjetivos sem correspondentes medidas objetivas, ou inclusão de populações heterogêneas com diversos períodos pós-operatórios (Argenson et al., 2013; Hamilton et al., 2015; Benedetto et al., 2019). Existe necessidade clara de estudos longitudinais prospectivos que comparem objetivamente o desempenho funcional entre diferentes tipos de implantes, utilizando metodologia rigorosa, sensores inerciais para quantificação de parâmetros biomecânicos, testes funcionais padronizados e questionários validados em momentos pré-definidos do período pós-operatório (Hamilton et al., 2015; De Vroey et al., 2018; Youn et al., 2020).

Este estudo foi desenvolvido fundamentado na hipótese central de que o desenho de prótese de joelho com platô móvel ultracongruente oferece melhor recuperação funcional em pacientes idosos quando comparado com próteses de platô fixo póstero-estabilizado, particularmente em parâmetros objetivos de marcha, mobilidade funcional avaliada por testes de desempenho e qualidade de vida relacionada à saúde (De Vroey et al., 2018; Canovas & Dagnneaux, 2018; Youn et al., 2020; Wenzel et al., 2023). Os resultados desta investigação podem auxiliar cirurgiões ortopédicos na seleção racional e informada do tipo de implante mais apropriado para cada paciente individual, potencialmente evitando custos desnecessários sem comprometer a longevidade funcional do implante e os resultados funcionais no seguimento de longo prazo (De Vroey et al., 2018; Canovas & Dagnneaux, 2018; Wenzel et al., 2023).

Além disso, este estudo contribui para a validação de metodologia de avaliação utilizando sensores inerciais portáteis em ambiente ambulatorial, estabelecendo fundamentos para avaliação padronizada de resultados funcionais pós-operatórios em futuras investigações clínicas (Pau et al., 2015; De Vroey et al., 2018).

2. OBJETIVOS

2.1 Objetivo Geral

Comparar objetivamente a recuperação funcional entre pacientes com mais de 50 anos submetidos a artroplastia total do joelho com desenho de implante de platô móvel ultracongruente versus (MB) platô fixo póstero-estabilizado (FB) (Figura 1), utilizando parâmetros de marcha quantificados e testes de desempenho funcional padronizados utilizando sensor inercial portátil e avaliações subjetivas de qualidade de vida, em um seguimento longitudinal prospectivo de 24 meses pós-operatórios.

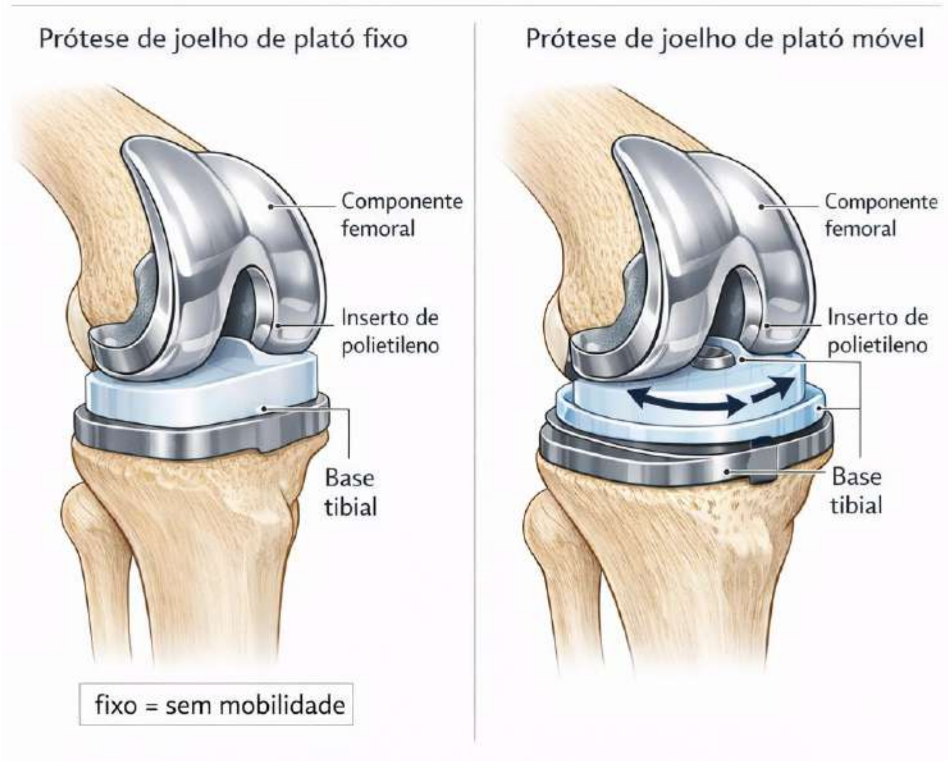

Figura 1 – Desenho esquemático das diferenças entre prótese pósteroestabilizada de platô fixo (FB) e prótese ultracongruente de platô móvel (MB)

2.2 Objetivos Específicos

a) Comparar, entre os grupos de implante (platô móvel ultracongruente MB versus platô fixo póstero-estabilizado FB), os parâmetros espaço-temporais da marcha obtidos por sensor inercial portátil (por exemplo, velocidade, cadência, comprimento do passo/passada, fases do ciclo e índices de simetria), nos momentos de 6, 12 e 24 meses de pós-operatório;

b) Avaliar e comparar a mobilidade funcional entre os grupos por meio de testes de desempenho padronizados instrumentados e/ou cronometrados (Timed Up and Go – TUG e Walk Test), nos mesmos momentos de seguimento;

c) Avaliar e comparar a capacidade funcional por meio do 2-Minute Walk Test (2MWT), considerando a evolução longitudinal intra e intergrupos aos 6, 12 e 24 meses

d) Avaliar e comparar a qualidade de vida e função locomotora autorrelatada entre os grupos através de questionários validados (WOMAC, GLFS-10P) nos momentos pré-determinados do seguimento;

e) Investigar a associação entre medidas objetivas (parâmetros de marcha e testes funcionais) e medidas subjetivas (WOMAC e GLFS-10P), estimando a magnitude e direção dessas correlações nos diferentes tempos de acompanhamento;

f) Identificar possíveis fatores associados a melhor recuperação funcional ao longo do tempo (por exemplo, idade, sexo, IMC, lateralidade, variáveis clínicas e cirúrgicas disponíveis), explorando seu efeito sobre desfechos objetivos e subjetivos;

g) Descrever a trajetória longitudinal dos desfechos funcionais em cada grupo e estimar o efeito do tempo, do tipo de prótese e da interação grupo × tempo nos principais desfechos;

h) Avaliar a aplicabilidade clínica do sensor inercial portátil como ferramenta de monitoramento ambulatorial, considerando sua utilidade para detectar mudanças longitudinais e assimetrias funcionais no seguimento pós-operatório.

2.3. Hipóteses

2.3.1. Hipótese Principal

O desenho de prótese de joelho com platô móvel ultracongruente (MB) oferece uma recuperação funcional superior em pacientes com mais de 50 anos quando comparado ao desenho de platô fixo póstero-estabilizado (FB), manifestada por uma melhora mais acentuada nos parâmetros cinemáticos da marcha e na mobilidade funcional ao longo de 24 meses de seguimento.

2.3.2. Hipóteses Secundárias

- Cinemática da Marcha: Pacientes do grupo MB apresentarão valores significativamente maiores de velocidade de marcha, cadência e comprimento do passo, além de uma melhor simetria espacial e temporal, quantificados pelo sensor inercial *G-Walk*®, em comparação ao grupo FB.
- Mobilidade Funcional e Resistência: O grupo MB demonstrará um desempenho superior nos testes de campo, especificamente uma redução no tempo de execução do *Timed Up and Go* (TUG) e um aumento na distância percorrida no Teste de Caminhada de 2 Minutos (2MWT), refletindo melhor capacidade funcional e resistência aeróbica.
- Desfechos Reportados pelo Paciente (PROMs): Ambos os grupos apresentarão melhora significativa na qualidade de vida e redução da dor, porém o grupo MB exibirá escores superiores no *Western Ontario and McMaster Universities Osteoarthritis Index* (WOMAC) e no *Geriatric Locomotor Function Scale* (GLFS-10P) nos períodos de 12 e 24 meses.
- Trajetória Longitudinal: A evolução funcional não será linear, com o maior ganho de recuperação ocorrendo nos primeiros 6 meses para ambos os grupos, mas com o grupo MB mantendo uma trajetória de melhora ou estabilização superior no longo prazo (24 meses) em relação ao grupo FB.
- Correlação de Medidas: Existe uma correlação positiva e forte entre os parâmetros objetivos de marcha (cadência e velocidade via *G-Walk*®) e a percepção subjetiva

de funcionalidade do paciente (escore total do WOMAC), independentemente do tipo de implante utilizado.

3. METODOLOGIA

3.1 Desenho do Estudo

Estudo prospectivo e longitudinal comparando dois desenhos de implantes de prótese de joelho (platô móvel ultracongruente MB versus platô fixo póstero-estabilizado FB) em pacientes com mais de 50 anos submetidos a artroplastia total do joelho. O protocolo de pesquisa foi aprovado pelo Comitê de Ética em Pesquisa (CEP/CONEP) da Universidade Evangélica de Goiás - UniEvangélica (CAAE: 52052421.9.0000.5076 – aprovado em 28/07/2022 e renovado em 19/04/2024), Declaração de instituição coparticipante e todos os participantes assinaram Termo de Consentimento Livre e Esclarecido (TCLE) antes da inclusão no estudo.

3.2 População e Amostra

A determinação do tamanho amostral foi realizada por meio do software G*Power (versão 3.1.9.7), utilizando como base o teste estatístico de Análise de Variância (ANOVA) para Medidas Repetidas, focando na interação entre os fatores "tipo de prótese" (análise entre grupos) e "tempo de seguimento" (análise intragrupo).

Para o cálculo, adotaram-se os seguintes parâmetros bioestatísticos:

1. Tamanho de Efeito (*f*): Estabelecido em 0,35 (médio-alto). Esta escolha fundamenta-se na alta sensibilidade e acurácia do sensor inercial G-Walk® (BTS Bioengineering), capaz de detectar variações cinemáticas discretas que escalas clínicas convencionais poderiam negligenciar.

2. Poder Estatístico (1-β): 0,80.

3. Nível de Significância (α): 0,05.

4. Configuração do Desenho: Dois grupos independentes (Prótese ultracongruente com platô móvel e Prótese póstero-estabilizada com platô fixo) avaliados em três momentos distintos (6, 12 e 24 meses de pós-operatório), com correlação estimada entre medidas repetidas de 0,6.

O cálculo resultou em uma amostra mínima de 18 participantes (09 por grupo). Prevendo-se uma taxa de atrito (*attrition rate*) de aproximadamente 20% em virtude da natureza longitudinal do estudo (24 meses de acompanhamento), a amostra final foi ajustada para 22 participantes (11 por grupo), garantindo a robustez das inferências estatísticas e a manutenção do poder do teste.

3.3 Critérios de Inclusão

- Idade igual ou superior a 50 anos;
- Diagnóstico de osteoartrose primária avançada do joelho (Kellgren-Lawrence grau III ou IV);
- Indicação clínica de artroplastia total do joelho;
- Capacidade de deambular independentemente no pré-operatório;
- Capacidade cognitiva adequada para compreender instruções e preencher questionários.

3.4 Critérios de Exclusão

- Condições neurológicas que afetem marcha ou equilíbrio (Acidente Vascular Encefálico prévio, Doença de Parkinson, neuropatia periférica grave);

- Outras condições físicas que impeçam a deambulação;
- Insuficiência cardíaca descompensada ou arritmias não controladas;
- Revisão prévia de artroplastia do joelho ipsilateral;
- Infecção ativa ou história de infecção protética;
- Comorbidades que impeçam a adequada recuperação e reabilitação pós-operatória;
- Artroplastia prévia do quadril;
- Com histórico de fratura do joelho há menos de 12 meses;
- Incapacidade de compreender o protocolo ou seguir instruções.

3.5 Variáveis do Estudo

Variáveis Independentes

- Tipo de implante (platô móvel ultracongruente vs platô fixo póstero-estabilizado)
- Características demográficas: idade, sexo, índice de massa corporal (IMC)
- Lateralidade da artroplastia de joelho realizada
- Especificação do tipo de acesso cirúrgico utilizado (transquadricipital ou subvasto medial)

Variáveis Dependentes

- Parâmetros de marcha obtidos por sensores inerciais: velocidade, comprimento de passada, cadência, simetria
- Desempenho em testes funcionais (TUG, Walk Test, 2MWT)

- Escores de qualidade de vida (WOMAC, GLFS-10P)

3.6 Procedimentos de Coleta de Dados

Após a triagem e coletas dos dados demográficos, os sujeitos passaram pelas avaliações no ambulatório do Centro Estadual de Reabilitação e Readaptação Dr. Henrique Santillo - CRER em sala apropriada e reservada para aplicação do questionário WOMAC e GLFS-10P e das avaliações por meio dos testes: Walk Test, Timed Up Test e 2 minute walk test com utilização do sensor inercial G-Walk®. As avaliações foram individuais, com média de 10 minutos cada teste em três encontros (primeiro com 06 meses de pós-operatório, o segundo com 12 meses pós-operatório e terceiro com 24 meses pós-operatório). As avaliações ocorreram no ambulatório do Centro Estadual de Reabilitação e Readaptação Dr. Henrique Santillo - CRER sendo realizadas pelo mesmo médico e auxiliares para que não houvesse risco de viés, com experiência em coleta. As coletas ocorreram em conformidade com o protocolo abaixo:

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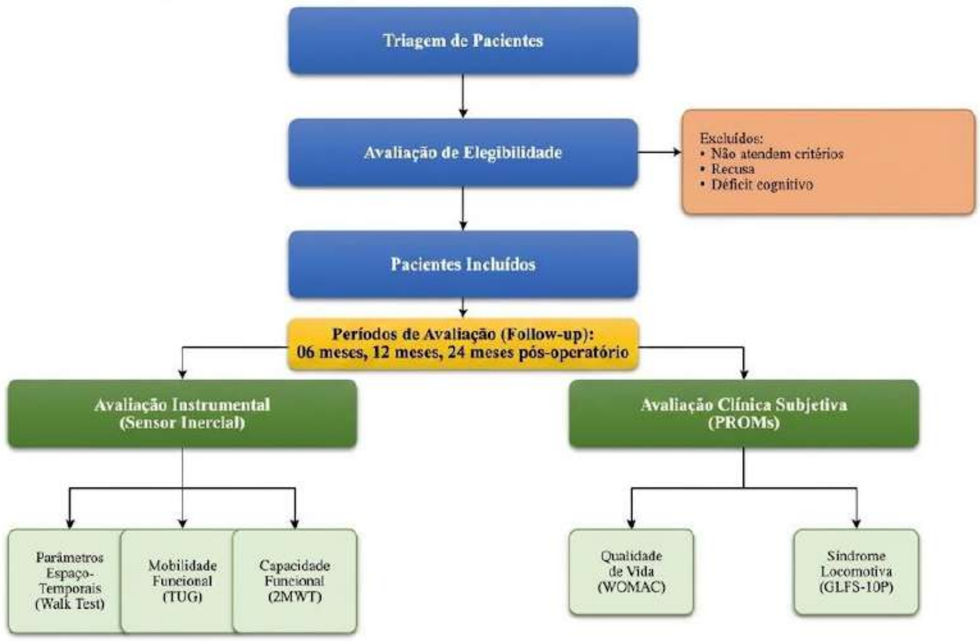

Figura 2 - Fluxograma do estudo

Avaliação funcional pós-operatória pelo paciente

A avaliação do resultado pós-operatório referido pelo paciente foi realizada pela aplicação dos questionários de WOMAC e GLFS-10P. O Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) é um questionário mundialmente recomendado de autoavaliação respondido pelo paciente para pesquisas clínicas de artrose do joelho. Originalmente desenvolvido como um questionário de 24 itens dividido em 3 seções independentes: dor (5 questões), rigidez articular (2 questões) e função física (17 questões). A resposta de cada pergunta é pontuada, com as pontuações sendo fornecidas para cada dimensão independente, e as pontuações mais altas representam maior dor e rigidez ou pior função. Apesar de inicialmente ser desenvolvido para pacientes com osteoartrose, hoje é utilizado em pesquisas para várias afecções musculoesqueléticas. As vantagens para a realização do WOMAC incluem a padronização da coleta de dados sobre os sintomas que não os relacionados exclusivamente com a artrose, e a descrição para a utilização para auxílio ao reconhecimento dos alvos terapêuticos (Lage et al, 2020). O questionário WOMAC foi traduzido e validado para a língua portuguesa, sendo um instrumento reprodutível e válido para a avaliação dos pacientes com osteoartrose. (Fernandes, 2003).

A avaliação do resultado pós-operatório referido pelo paciente também incluiu a aplicação da versão em português abreviada da Geriatric Locomotive Function Scale, o GLFS-10P. A Escala Geriátrica da Função Locomotora de 10 itens (GLFS-10P) é uma versão curta derivada da GLFS-25, especificamente desenvolvida para rastreamento do síndrome de locomoção/mobilidade em idosos, condição caracterizada por risco aumentado de limitação para marcha e dependência nas atividades de vida diária em decorrência de disfunção musculoesquelética. O instrumento é composto por 10 questões que abordam, por meio de auto-relato, dificuldades em atividades funcionais cotidianas, mobilidade, participação social e preocupações relacionadas a quedas e à capacidade de deambulação futura, com pontuação total que varia de 0 a 40 pontos, em que escores mais elevados indicam pior função locomotora. No estudo de validação brasileiro, o GLFS-10P apresentou boas propriedades psicométricas, com consistência interna adequada e excelente capacidade de discriminação para o diagnóstico de síndrome locomotora (ponto de corte ≥10 pontos, sensibilidade de 96,5% e especificidade de 86,2%), configurando-se como instrumento simples, de rápida aplicação e adequado para uso em serviços com grande demanda assistencial (Alves et al., 2022).

Avaliação dos parâmetros espaço temporais da marcha por meio do Walk Test

A avaliação dos parâmetros espaço temporais da marcha foi realizada por meio do sensor inercial (G-Walk®, BTS Bioengineering S.p.A. Itália) (Figura 3) com análise da marcha por meio do walk test, previamente validado na avaliação de marcha para indivíduos saudáveis e aqueles que possuem doença de Parkinson (Bugané et al., 2012;

PAU et al., 2015). O G-Walk® portátil é um sistema wireless de sensores inerciais para análise do movimento humano. Os sensores são controlados por uma unidade de registro de dados (até 16 elementos) por uma comunicação de rádio do tipo ZigBee. Cada sensor possui 62mm × 36mm x 16mm de dimensões, um peso de 60g, e é composto por um acelerômetro de três eixos (escala máxima de ± 6g), um giroscópio de 3 eixos (escala completa ± 300°/s) e um magnetômetro de 3 eixos (escala completa ± 6 Gauss). Este dispositivo foi calibrado com a aceleração da gravidade imediatamente após a fabricação. Para este trabalho foi utilizado apenas um dispositivo que coletará os dados a uma frequência de amostragem de 50Hz. Os dados do sensor inercial foram transmitidos via Bluetooth para um computador e processados usando software próprio (BTS G-STUDIO®, versão: 2.6.12.0), que fornece automaticamente os parâmetros (Galli et al., 2015).

Figura 3 - G-Walk®, BTS Bioengenharia

Comprimento mesmo pé (m); Velocidade de marcha: velocidade instantânea média dentro do ciclo de marcha (m s-1); Cadência: número de etapas por minuto (passos min-1); Posição e duração da fase de balanço: expressa como uma porcentagem do ciclo da marcha, representando a proporção de um ciclo de marcha que envolve suporte de pé (do calcanhar para o pé com o mesmo pé) e balanço do membro inferior; Duração do apoio duplo: a duração da fase de apoio em ambos os pés, expressa como uma porcentagem do ciclo de marcha; Angulação da pelve (inclinação, obliquidade e rotação) do passo: distância entre dois contatos de calcanhar consecutivos.

Avaliação da mobilidade funcional por meio o teste Timed Up Go (TUG)

A avaliação da mobilidade foi realizada utilizando o sensor inercial G-Walk®, BTS Bioengenharia (Figura 4) que é amplamente utilizado para avaliar a mobilidade funcional. Também quantifica em segundos o tempo que o indivíduo realiza a tarefa, ou seja, em quantos segundos ele se levanta de uma cadeira padronizada sem apoio e braços, deambula três metros, vira, volta rumo à cadeira e se senta novamente (Figura 3) (Podsiadlo & Richardson, 1991). Os sujeitos foram instruídos a realizar o teste numa velocidade auto selecionada, de forma segura. O teste foi realizado duas vezes, sendo a primeira para familiarização.

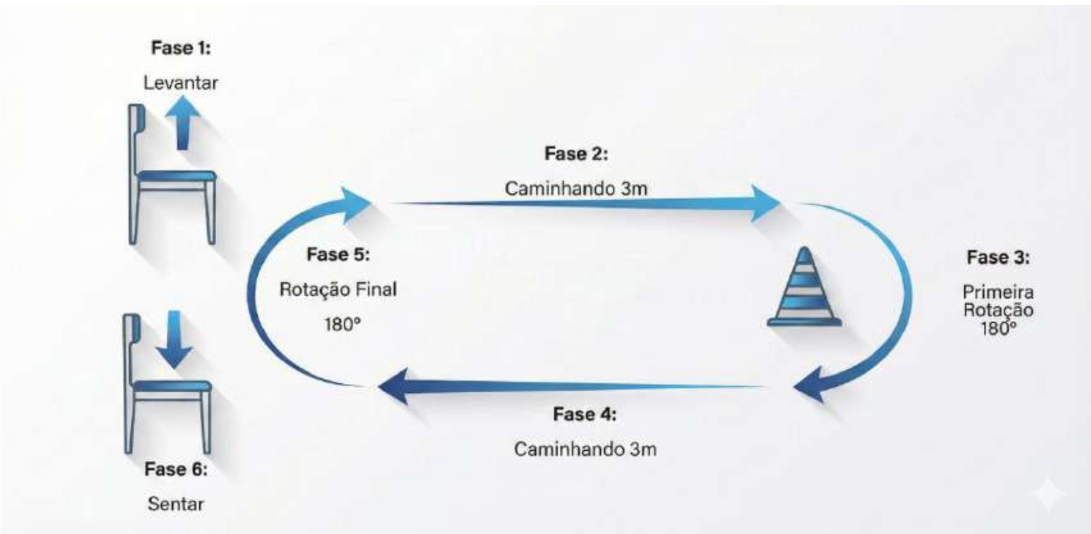

Figura 4 - Teste Timed Up and Go. Adaptado de Galli et al, 2015

Avaliação da capacidade funcional por meio do 2 minutes walk test

A avaliação da capacidade funcional foi realizada por meio do teste de 2 minutes walk test validado onde os sujeitos foram instruídos a caminhar na sua velocidade normal no percurso delimitado de acordo com a figura 4 sem paradas. Foi permitido a utilização de órtese se os sujeitos necessitassem (Unnanuntana et al., 2018).

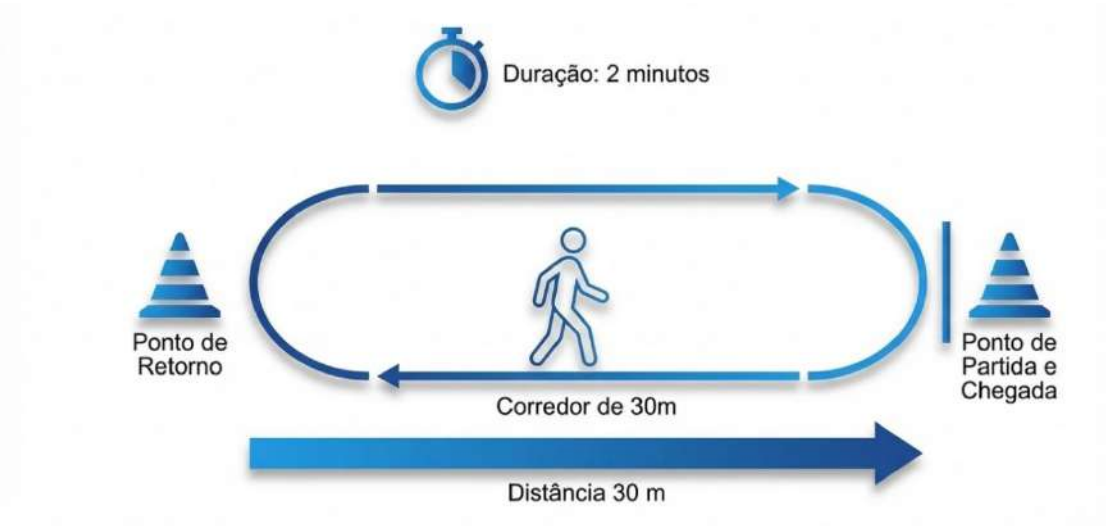

Figura 5 - 2 minutes walk test : Adaptado de Rosado Calatayud et al., 2016.

3.7 Análise Estatística

3.7.1 Delineamento e Análise Descritiva

O presente estudo foi caracterizado como um ensaio clínico prospectivo e longitudinal, com alocação dos participantes em dois grupos de tratamento: prótese de platô tibial fixo póstero-estabilizado (Grupo FB) e prótese de platô tibial móvel ultracongruente (Grupo MB). As avaliações funcionais e subjetivas foram realizadas em múltiplos momentos ao longo do tempo (6, 12 e 24 meses de pós-operatório), permitindo a análise da recuperação funcional longitudinal.

A análise descritiva foi utilizada para caracterizar a amostra. A normalidade da distribuição das variáveis contínuas (idade, peso, altura, IMC) foi avaliada pelo teste de Shapiro-Wilk. Dados com distribuição normal foram apresentados como média e desvio padrão (DP), enquanto dados não normais foram descritos por mediana e intervalo interquartil (IIQ). Variáveis categóricas (sexo, lateralidade) foram apresentadas em frequências absolutas (n) e relativas (%).

A homogeneidade basal entre os grupos FB e MB foi verificada utilizando o Teste t de Student para amostras independentes (dados paramétricos), o Teste de Mann-Whitney U (dados não paramétricos) e o Teste Qui-quadrado de Pearson ou Teste Exato de Fisher (dados categóricos).

3.7.2 Análise dos Desfechos Longitudinais

A análise dos desfechos primários e secundários foi realizada por meio de múltiplas abordagens estatísticas para capturar a complexidade dos dados.

3.7.3 Análise Intergrupos

A comparação dos desfechos contínuos (TUG, 2MWT, WOMAC, GLFS-10P, parâmetros da marcha) entre os grupos FB e MB, em cada ponto de tempo (6, 12 e 24 meses), foi realizada utilizando o Teste de Mann-Whitney U, devido ao tamanho da amostra e à distribuição não paramétrica da maioria das variáveis.

3.7.4 Análise da Evolução Temporal Intragrupo

Para avaliar a evolução funcional dentro de cada grupo ao longo do tempo (e.g., 6 vs. 12 meses, 12 vs. 24 meses), foi empregado o Teste de Wilcoxon para amostras pareadas. Esta análise permitiu identificar se as mudanças observadas entre os períodos de avaliação eram estatisticamente significantes para cada tipo de prótese isoladamente.

3.7.5 Modelagem da Trajetória Longitudinal

Para uma análise mais robusta da trajetória dos desfechos ao longo do tempo, foram utilizados Modelos Lineares de Efeitos Mistos (MLEM). Esta abordagem avançada é ideal para dados longitudinais, pois permite modelar a correlação entre as medidas repetidas de um mesmo indivíduo e manejar adequadamente os dados faltantes. O modelo foi estruturado para avaliar os efeitos fixos de Grupo (FB vs. MB), Tempo (6, 12, 24 meses) e a interação Grupo × Tempo. A interação foi o principal foco desta análise, pois indica se a trajetória de recuperação difere entre os dois tipos de implante. Um intercepto aleatório por participante foi incluído para controlar a variabilidade basal entre os indivíduos.

Os resultados do modelo de efeitos mistos para o TUG indicaram um efeito significante do tempo (coeficiente = 0,409, $p < 0,001$), demonstrando que a duração do TUG aumenta ao longo do seguimento. Não houve efeito significante do grupo ($p = 0,799$) nem da interação grupo × tempo ($p = 0,585$), indicando que ambos os grupos seguem trajetórias similares.

3.7.6 Associação entre Medidas Objetivas e Subjetivas

Para investigar a associação entre as medidas funcionais objetivas (TUG, 2MWT) e as medidas de percepção subjetiva do paciente (escores WOMAC e GLFS-10P), foi calculado o coeficiente de correlação de Spearman (ρ). Esta análise foi realizada de forma transversal nos momentos de 12 e 24 meses para avaliar a força e a direção da relação entre o que o paciente sente e o que ele consegue realizar funcionalmente.

3.7.7 Fatores Associados à Recuperação Funcional

Com o objetivo de identificar os fatores preditores de uma melhor recuperação funcional, foram construídos modelos de regressão linear múltipla. Os desfechos funcionais em 24 meses (TUG e 2MWT) foram definidos como variáveis dependentes. As variáveis independentes (preditoras) testadas no modelo incluíram o grupo de tratamento (FB vs. MB), idade, sexo e IMC, permitindo avaliar a contribuição relativa de cada fator para o resultado clínico em longo prazo.

3.7.8 Análise de Assimetria da Marcha

Para avaliar a aplicabilidade clínica do sensor inercial no monitoramento de assimetrias, foi calculado um Índice de Assimetria a partir dos dados do Walk Test, definido como o valor absoluto da diferença entre o Índice de Qualidade da Marcha do lado direito e do lado esquerdo. A evolução deste índice foi comparada entre os grupos ao longo do tempo utilizando o Teste de Mann-Whitney U.

3.7.9 Nível de Significância e Software

Para todas as análises estatísticas, o nível de significância foi fixado em $\alpha = 0{,}05$. Resultados com p-valor inferior a este limiar foram considerados estatisticamente significantes. Todas as análises e a geração de gráficos foram realizadas utilizando a linguagem de programação Python (versão 3.11) e suas bibliotecas científicas, incluindo pandas, scipy, statsmodels, matplotlib e seaborn.

4. RESULTADOS

4.1 Características Demográficas e Clínicas da Amostra

A análise final incluiu um total de 24 participantes que completaram o seguimento mínimo, sendo 12 alocados no grupo Platô Fixo (FB) e 12 no grupo Platô Móvel (MB). A caracterização detalhada da amostra está apresentada na Tabela 1.

Tabela 1. Características demográficas e clínicas da amostra, estratificadas por grupo de tratamento.

Variável	**FB (n=12)**	**MB (n=12)**	**p-valor**
Idade (anos)	66,2 ± 7,6	64,3 ± 7,4	0,487
IMC (kg/m²)	31,2 ± 4,9	32,0 ± 5,4	0,817
Peso (kg)	80,2 ± 12,5	84,5 ± 16,1	0,543
Altura (m)	1,60 ± 0,09	1,62 ± 0,08	0,400
Sexo			
Feminino, n (%)	8 (66,7%)	7 (58,3%)	1,000
Masculino, n (%)	4 (33,3%)	5 (41,7%)	
Lateralidade			
Direita, n (%)	10 (83,3%)	7 (58,3%)	0,371
Esquerda, n (%)	2 (16,7%)	5 (41,7%)	

Legenda: Valores apresentados como média ± desvio padrão ou n (%). IMC: Índice de Massa Corporal. O p-valor refere-se à comparação entre os grupos FB e MB (Teste de Mann-Whitney U para variáveis contínuas e Teste Exato de Fisher para categóricas).

Os grupos de tratamento (FB e MB) foram considerados homogêneos no início do estudo, não apresentando diferenças estatisticamente significantes em nenhuma das variáveis demográficas e clínicas avaliadas.

4.2 Análise Intergrupos dos Desfechos Funcionais

A comparação direta entre os grupos FB e MB, em cada período de avaliação, não revelou diferenças estatisticamente significantes para nenhum dos desfechos primários ou secundários (Tabela 2) e caracterização por desfecho por grupo e período foram expostas na Figura 6.

Tabela 2. Resumo dos desfechos funcionais e subjetivos por grupo de tratamento e período de avaliação.

Desfecho	**Período**	**FB (média ± DP)**	**n**	**MB (média ± DP)**	**n**	**p-valor**
TUG (s)	6m	14,96 ± 3,72	11	14,75 ± 3,62	10	0,751
	12m	14,50 ± 2,37	10	14,56 ± 2,70	10	0,970
	24m	22,14 ± 5,30	6	20,31 ± 5,87	9	0,456
2MWT (m)	6m	73,8 ± 14,7	11	70,8 ± 16,4	10	0,833
	12m	88,3 ± 14,8	11	92,9 ± 17,8	10	0,417
	24m	64,2 ± 23,0	6	84,3 ± 21,5	9	0,262
WOMAC Total	12m	5,9 ± 6,0	17	5,6 ± 4,5	17	0,782
	24m	2,2 ± 7,2	18	2,1 ± 3,8	18	0,303

Desfecho	Período	FB (média ± DP)	n	MB (média ± DP)	n	p-valor
GLFS-10P Total	12m	5,8 ± 4,4	17	6,6 ± 3,1	17	0,508
	24m	2,0 ± 5,6	17	2,7 ± 4,1	17	0,307

Legenda: TUG: Timed Up and Go; 2MWT: Teste de Caminhada de 2 Minutos; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; GLFS-10P: Geriatric Locomotive Function Scale. O p-valor refere-se à comparação entre os grupos FB e MB pelo Teste de Mann-Whitney U.

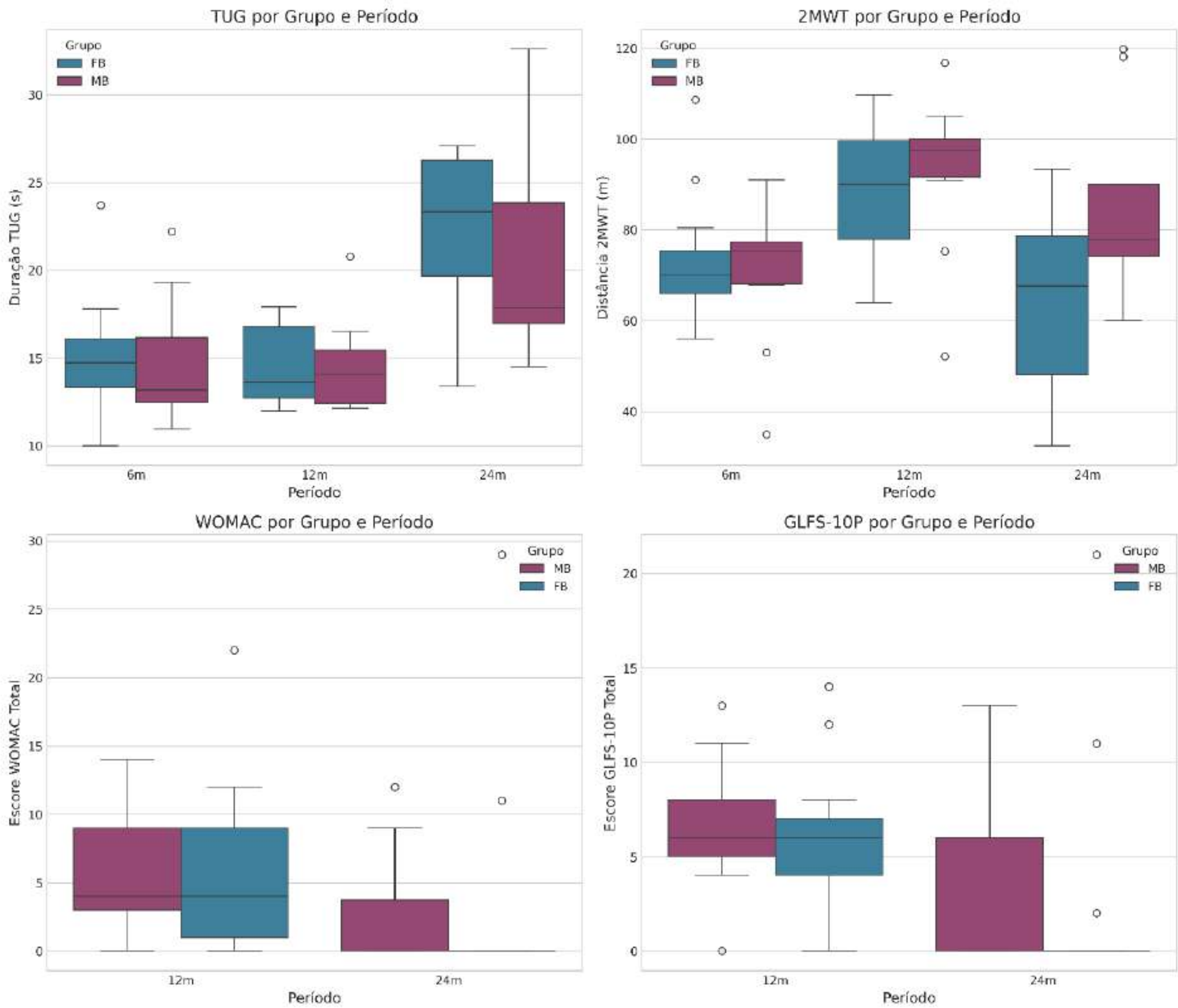

Figura 6. Boxplots Comparativos dos Desfechos por Grupo e Período

4.3 Evolução Temporal e Análise Intragrupo

A análise da evolução temporal dentro de cada grupo revelou insights importantes sobre a trajetória de recuperação (Tabela 3).

Tabela 3. Análise da evolução temporal intragrupo para os desfechos funcionais (Teste de Wilcoxon).

Desfecho	**Grupo**	**Comparação**	**n**	**Δ (média)**	**p-valor**
TUG (s)	FB	6m vs 12m	10	-0,69	> 0,999
	FB	12m vs 24m	5	+7,36	0,062
	MB	6m vs 12m	8	-0,56	0,641
	MB	12m vs 24m	7	+6,85	0,016*
2MWT (m)	FB	6m vs 12m	10	+14,0	0,020*
	FB	12m vs 24m	5	-23,8	0,062
	MB	6m vs 12m	8	+21,7	0,016*
	MB	12m vs 24m	7	-17,9	0,078
WOMAC	FB	12m vs 24m	17	-3,5	0,047*
	MB	12m vs 24m	16	-2,8	0,172
GLFS-10P	FB	12m vs 24m	17	-3,8	0,040*
	MB	12m vs 24m	17	-3,9	0,020*

Legenda: * $p < 0,05$. Δ (média) representa a mudança média no desfecho (positivo = piora para TUG, melhora para 2MWT; negativo = melhora para WOMAC e GLFS-10P).

4.3.1 Timed Up and Go (TUG)

Não houve melhora significativa do TUG entre 6 e 12 meses para nenhum dos grupos. No entanto, observou-se uma piora estatisticamente significante no desempenho do TUG para o Grupo MB entre 12 e 24 meses (Δ = +6,85s, p = 0,016), com um aumento médio de 6,85 segundos. Uma tendência similar de piora foi observada no Grupo FB (Δ = +7,36s, p = 0,062). O gráfico de trajetórias individuais (Figura 7) ilustra essa variabilidade e a tendência geral de piora no período final.

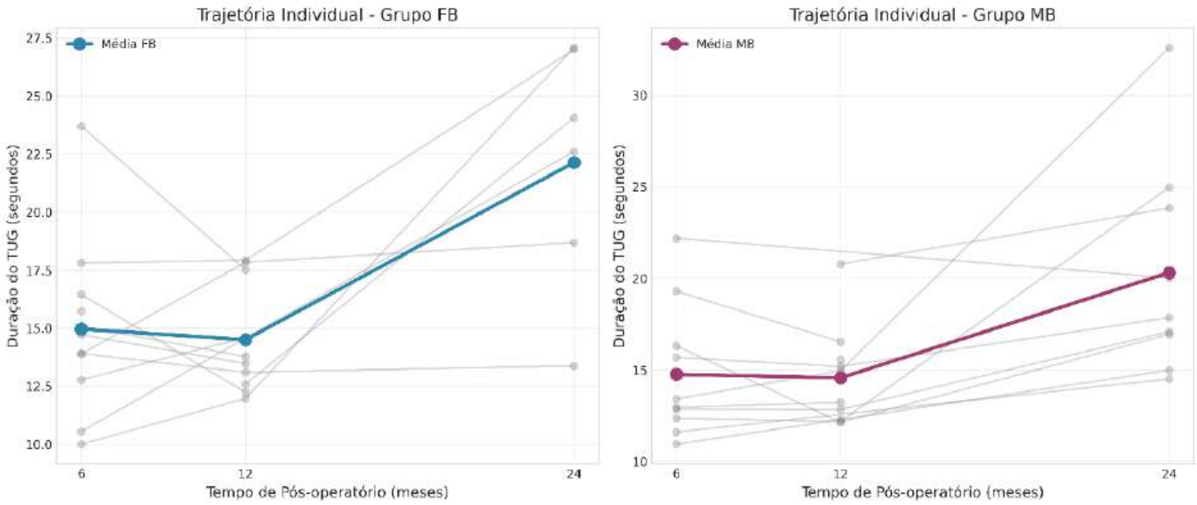

Figura 7. Trajetória Individual do TUG por Grupo

4.3.2 2 Minute Walk Test (2MWT)

Ambos os grupos apresentaram uma melhora estatisticamente significante na distância percorrida no 2MWT entre 6 e 12 meses (FB: Δ = +14,0m, p = 0,020; MB: Δ = +21,7m, p = 0,016). Contudo, entre 12 e 24 meses, ambos os grupos mostraram uma tendência de queda no desempenho, embora sem significância estatística (FB: p = 0,062; MB: p = 0,078).

4.3.3 Questionários WOMAC e GLFS-10P

Ambos os grupos apresentaram uma melhora estatisticamente significante nos escores WOMAC e GLFS-10P entre 12 e 24 meses, indicando uma melhora na percepção de dor e função. No grupo FB, o escore WOMAC reduziu em média 3,5 pontos (p =

0,047) e o GLFS-10P em 3,8 pontos (p = 0,040). No grupo MB, o GLFS-10P reduziu em média 3,9 pontos (p = 0,020).

4.4 Correlação entre Desfechos Objetivos e Subjetivos

A análise de correlação de Spearman revelou associações importantes, principalmente entre os próprios questionários (Tabela 4 e Figura 3).

Tabela 4. Matriz de correlação de Spearman (ρ) entre os desfechos.

Correlação	**12 meses (ρ)**	**p-valor**	**24 meses (ρ)**	**p-valor**
TUG vs 2MWT	-0,70	<0,001*	-0,48	0,096
TUG vs WOMAC	-0,14	0,582	0,20	0,487
2MWT vs WOMAC	-0,02	0,931	-0,22	0,451
WOMAC vs GLFS-10P	0,82	<0,001*	0,79	<0,001*

A correlação mais forte e consistente foi entre os escores WOMAC e GLFS-10P, tanto aos 12 meses (ρ = 0,82) quanto aos 24 meses (ρ = 0,79), indicando alta concordância entre as medidas de dor/função e a percepção de capacidade locomotora.

Uma correlação forte e negativa foi encontrada entre TUG e 2MWT aos 12 meses (ρ = -0,70, $p < 0,001$), como esperado (melhor desempenho no TUG está associado a maior distância no 2MWT). Essa correlação enfraqueceu e perdeu significância aos 24 meses.

As correlações entre os testes funcionais objetivos (TUG, 2MWT) e os questionários subjetivos (WOMAC, GLFS-10P) foram, em geral, fracas e não significantes (Figura 8).

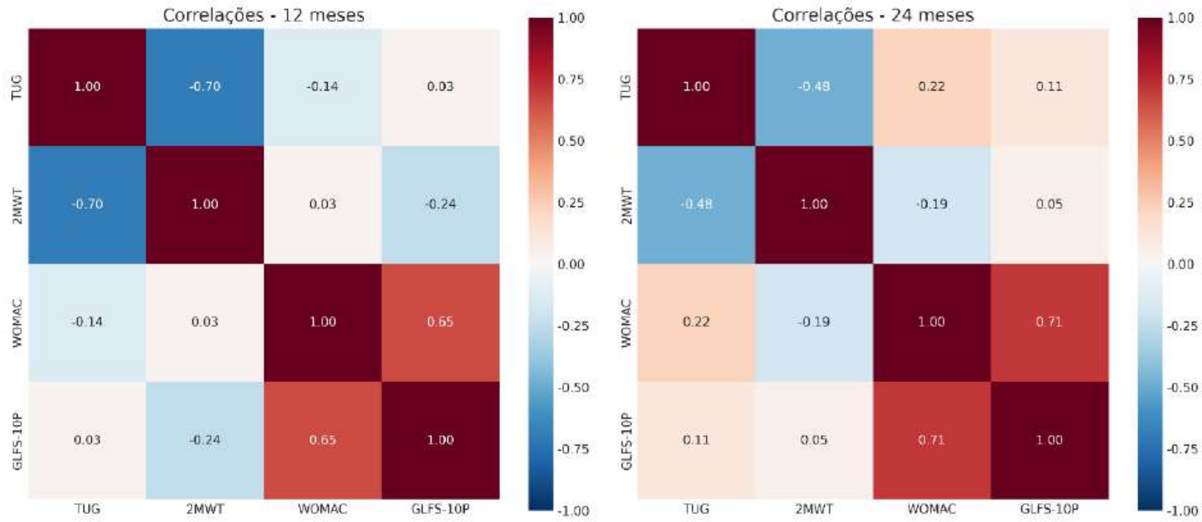

Figura 8. Heatmap de Correlações entre Desfechos

4.5 Fatores Preditores da Recuperação Funcional

Os modelos de regressão linear múltipla para prever os desfechos em 24 meses não identificaram o tipo de prótese, idade, sexo ou IMC como preditores estatisticamente significantes do desempenho no TUG ou 2MWT. O modelo para o 2MWT apresentou um R^2 de 0,45, porém nenhuma variável individual atingiu significância estatística ($p >$ 0,05 para todas).

4.6 Análise de Assimetria da Marcha

Em relação à assimetria da marcha, ambos os grupos apresentaram uma tendência de redução da assimetria entre 6 e 24 meses (Figura 9). O índice de assimetria médio reduziu de 5,7% (6m) para 2,3% (24m) no grupo FB, e de 5,9% (6m) para 2,4% (24m) no grupo MB. Não houve diferença estatisticamente significante entre os grupos FB e MB em nenhum dos períodos avaliados ($p > 0,05$).

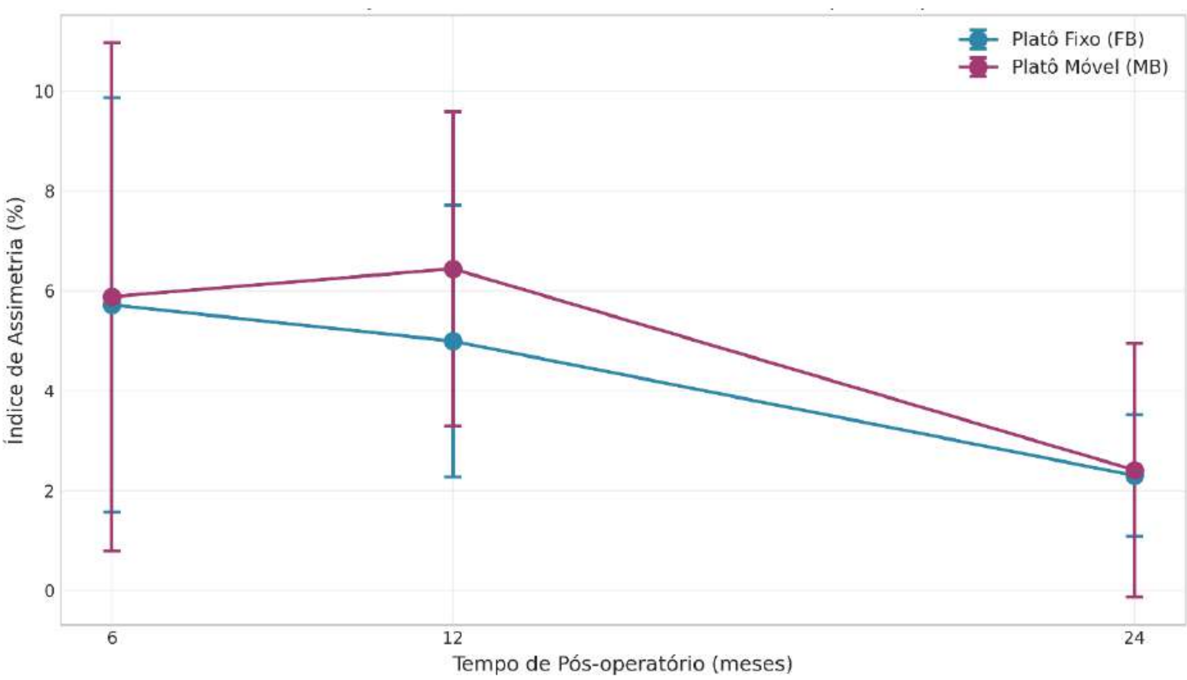

Figura 9. Evolução do Índice de Assimetria da Marcha

4.7 Síntese dos Achados

Em síntese, os resultados deste estudo demonstram que (Figura 10):

1. Não houve diferença estatisticamente significante entre os grupos FB e MB em nenhum dos desfechos funcionais ou subjetivos avaliados, nos períodos de 6, 12 e 24 meses de pós-operatório, sugerindo equivalência funcional entre os dois tipos de implante.
2. Pico de Recuperação em 12 Meses: Os dados sugerem que a recuperação funcional, medida pelo 2MWT, atinge um pico em 12 meses, com uma melhora significativa em relação aos 6 meses. Após este período, observa-se uma tendência de declínio.
3. Piora Funcional Tardia (TUG): A análise intragrupo revelou uma piora significativa no TUG para o grupo MB (e uma tendência no grupo FB) entre 12 e 24 meses. Este achado inesperado, visível nas trajetórias individuais, sugere que a mobilidade funcional pode se deteriorar em um prazo mais longo.

4 Melhora Subjetiva Contínua: Apesar da piora nos testes funcionais objetivos, os escores de WOMAC e GLFS-10P continuaram a melhorar entre 12 e 24 meses, indicando uma melhora na percepção de dor e função pelos pacientes.

5 Desconexão Objetivo-Subjetivo: A fraca correlação entre os testes funcionais objetivos e os questionários subjetivos sugere que a percepção de melhora do paciente não se traduz diretamente em um melhor desempenho em testes cronometrados, destacando a importância de uma avaliação multidimensional.

6 Redução da Assimetria: Ambos os grupos apresentaram redução do índice de assimetria da marcha ao longo do tempo, indicando uma melhora na simetria do padrão de marcha, sem diferenças entre os tipos de implante.

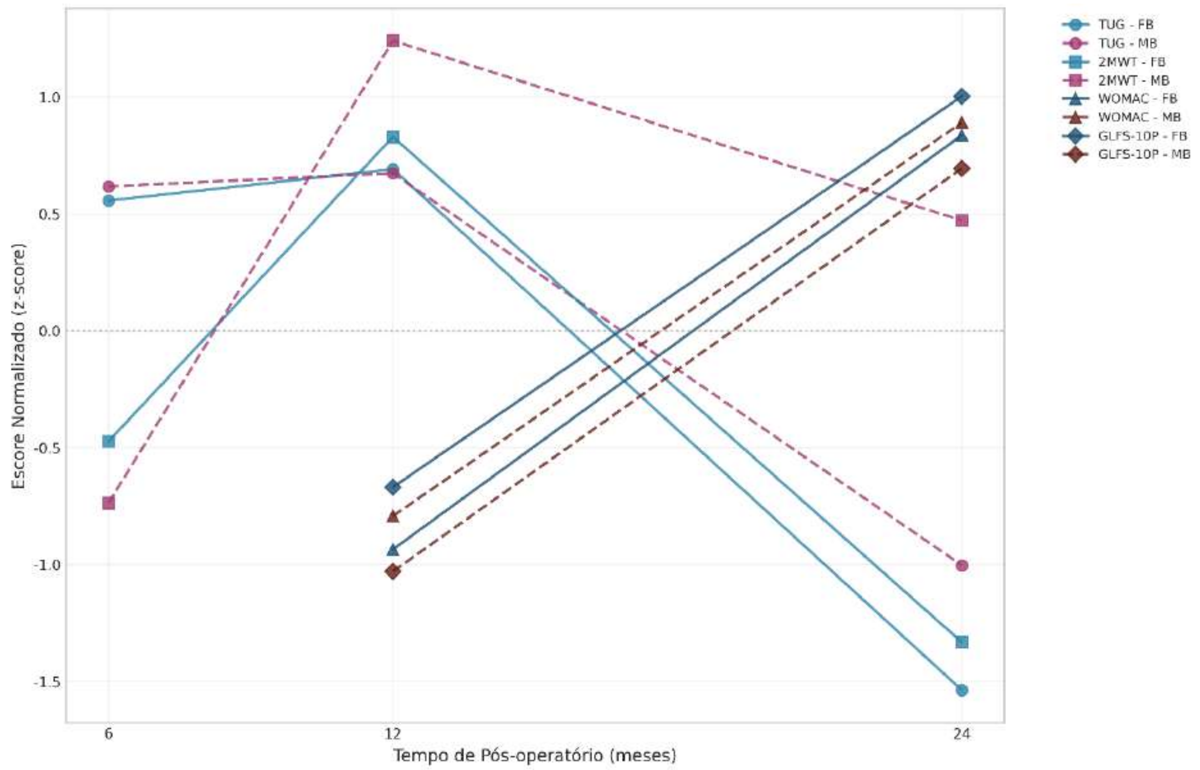

Figura 10. Evolução Comparativa dos Desfechos

5. DISCUSSÃO

O presente estudo longitudinal prospectivo foi delineado com o objetivo central de comparar a recuperação funcional de pacientes submetidos à artroplastia total do joelho (ATJ) com dois desenhos distintos de implantes: platô móvel ultracongruente (MB) e platô fixo póstero-estabilizado (FB). A principal hipótese desta investigação afirmava que o desenho de platô móvel, por suas características biomecânicas teóricas, conferiria uma recuperação funcional superior, manifestada por melhores parâmetros cinemáticos da marcha e mobilidade funcional ao longo de 24 meses de seguimento. Contudo, o achado mais relevante deste estudo foi a refutação dessa hipótese, demonstrando teórica equivalência funcional entre os dois tipos de prótese em todos os desfechos objetivos e subjetivos avaliados, no período avaliado.

5.1 Equivalência Funcional entre Próteses de Platô Fixo e Platô Móvel

O resultado primário desta pesquisa revelou a ausência de diferenças estatisticamente significantes entre os grupos FB e MB no que tange aos parâmetros espaço-temporais da marcha, testes de desempenho funcional (TUG e 2MWT) e desfechos relatados pelos pacientes (WOMAC e GLFS-10P) nos períodos de 6, 12 e 24 meses de pós-operatório. Este achado de equivalência funcional, embora contrário à hipótese inicial do estudo, está em ampla consonância com um corpo robusto e crescente de evidências na literatura ortopédica. Múltiplos estudos recentes e revisões sistemáticas têm consistentemente falhado em demonstrar a superioridade clínica dos implantes de platô móvel sobre os de platô fixo.

Estudo retrospectivo de longo prazo corrobora diretamente nossos achados, concluindo que, embora os implantes MB tenham demonstrado maior rotação axial tibial

(23,1° ± 4,5° versus 19,4° ± 4,2°; p = 0,003), essa vantagem cinemática não se traduziu em desfechos funcionais superiores ou maior sobrevida do implante em comparação com os desenhos FB (Ramos Guarderas et al., 2025). Os autores reportaram que ambos os grupos apresentaram melhora funcional significativa ($p < 0{,}001$), sem diferenças significativas nos escores IKDC ou Kujala, e com sobrevida do implante de 96,3% (MB) versus 95,7% (FB) em seguimento de até 15 anos. De forma similar, meta-análise de incluindo ensaios randomizados com seguimento mínimo de 12 meses não encontrou diferenças em taxas de revisão, afrouxamento, escores funcionais, amplitude de movimento ou achados radiográficos entre os dois tipos de implante (Hantouly et al., 2021).

Ensaio clínico randomizado prospectivo comparando 49 ATJs com FB versus 49 com MB, avaliaram consciência articular, crepitação, amplitude de movimento e escores funcionais, não encontrando diferenças significativas em nenhum dos desfechos avaliados (Sohn et al., 2022). Os autores concluíram que a ATJ com MB não demonstrou benefícios sobre a FB, deixando a seleção do implante a critério do cirurgião. Outro estudo com 88 pacientes e 13 anos de seguimento, avaliando VAS, ROM, KSS e WOMAC, também não observaram diferenças clínicas ou radiográficas relevantes entre os grupos (Kim et al., 2024).

A convergência de nossos resultados com essas investigações de alta qualidade reforça a conclusão de que, para a maioria dos pacientes, a escolha entre um desenho de platô fixo e móvel pode não ser um fator determinante para o resultado funcional final, transferindo a decisão para outros fatores como preferência do cirurgião, custo e experiência com o sistema.

Revisão sistemática comparando desenhos ultracongruentes com póstero-estabilizados e com retenção do cruzado posterior, concluíram que "os dados disponíveis demonstram que não há diferenças clínicas entre os insertos CR, PS e UC em estudos de curto prazo terminando em torno de 2 anos após a cirurgia" (Wenzel et al., 2023). Este achado é particularmente relevante para nosso estudo, que utilizou um desenho ultracongruente no grupo MB, reforçando que as vantagens teóricas desses desenhos não se traduzem em benefícios clínicos mensuráveis.

5.2 Trajetória Longitudinal da Recuperação e o Declínio Funcional Tardio

Um dos achados intrigantes deste estudo foi a trajetória de recuperação não linear observada nos testes funcionais objetivos. A capacidade funcional, avaliada pela distância percorrida no 2MWT, demonstrou um pico de melhora em 12 meses de pós-operatório, com incremento significativo em relação aos 6 meses (FB: +14,0 m, $p = 0,020$; MB: +21,7 m, $p = 0,016$), seguido por uma tendência de declínio aos 24 meses. De forma ainda mais contundente, o desempenho no teste TUG apresentou uma deterioração estatisticamente significante entre 12 e 24 meses, particularmente no grupo MB ($\Delta = +6,85$ s; $p = 0,016$), com uma tendência similar no grupo FB ($\Delta = +7,36$ s; $p = 0,062$). Este declínio funcional tardio em uma medida objetiva de mobilidade contrasta com a melhora contínua observada nos escores subjetivos de WOMAC e GLFS-10P no mesmo período.

Este padrão de recuperação com um pico em aproximadamente um ano, seguido de uma estabilização ou declínio, já foi sugerido na literatura. Estudo prospectivo de 5 anos, relataram que "uma melhora significativa ainda foi observada 5 anos após a cirurgia. Entretanto, o melhor resultado foi reportado em 1 ano, indicando um declínio de 1 a 5 anos após a cirurgia" (Nilsdotter et al., 2009). Outros autores identificaram duas trajetórias distintas de recuperação de dor e função nos primeiros 6 meses após a ATJ, com a melhora acelerada ocorrendo predominantemente neste período inicial (Yang et al., 2019).

A piora funcional observada neste estudo pode ser parcialmente atribuída ao processo natural de envelhecimento e à perda de massa muscular e função (sarcopenia) que se acentua na população idosa. Autores demonstraram a existência de uma "idade crítica", em torno de 68 a 70 anos, na qual o declínio funcional se inicia independentemente da qualidade da cirurgia de ATJ (Pitta et al., 2019). Os autores encontraram relações não-lineares significativas entre idade e subdomínios do KOOS, com pontos de inflexão em 70 anos para KOOS Symptom e 68 anos para KOOS Pain, KOOS ADL e LEAS. Considerando que a idade média de nossa coorte foi de aproximadamente 65 anos no momento da cirurgia, é esperado que os participantes pudessem entrar nessa janela de declínio funcional relacionado à idade durante o segundo ano de acompanhamento.

Autores demonstraram que indivíduos com tempo de TUG ≥ 10,1 segundos e idade ≥ 72 anos antes da cirurgia apresentaram o pior desempenho no TUG 6 meses após a cirurgia (Bade et al., 2012). Outro estudo corrobora com esses achados, indicando que pacientes com TUG pré-operatório superior a 10,1 segundos e idade superior a 72 anos demonstraram declínio na função motora (Ito et al., 2021). Este fenômeno demonstra a importância de estratégias de reabilitação contínuas e programas de exercícios de manutenção a longo prazo para mitigar os efeitos do envelhecimento sobre os ganhos obtidos com a ATJ.

Autores reportaram baixa correlação entre parâmetros de marcha e qualidade de vida em pacientes com ATJ, com velocidade média de marcha de 0,95 ± 0,19 m/s, cadência de 105,6 ± 9,9 passos/min e comprimento da passada de 1,25 ± 0,17 m (Freijo et al., 2023). Essa dissociação tem implicações clínicas importantes, pois a satisfação do paciente e a melhora nos escores subjetivos podem mascarar um declínio funcional subjacente que, se não abordado, pode levar a um risco aumentado de quedas e perda de independência a longo prazo.

5.3 A Dissociação entre Medidas Objetivas e Subjetivas

Outro achado deste estudo foi a fraca correlação entre os desfechos funcionais objetivos (parâmetros de marcha, TUG, 2MWT) e as medidas subjetivas relatadas pelos pacientes (WOMAC, GLFS-10P). Enquanto os pacientes continuaram a relatar melhora na dor, rigidez e função percebida entre 12 e 24 meses, seu desempenho em testes cronometrados e quantificados de mobilidade e resistência piorou. Esta desconexão entre a percepção do paciente e seu desempenho funcional objetivo é um tema de intenso debate e investigação.

Estes achados são corroborados por um estudo utilizando dados do Osteoarthritis Initiative (OAI), concluíram que "não há uma forte associação entre os desfechos relatados pelos pacientes (PROMs) e os testes funcionais padronizados" em pacientes com osteoartrose de joelho ou que receberam uma ATJ (Hill et al., 2023). Os autores reportaram correlações fracas entre KOOS, WOMAC, SF-12, ICOAP e testes funcionais (400m walk pace, chair stand pace, 20m pace), com coeficientes de correlação variando de 0,00 a 0,30 na coorte ATJ. Os autores postulam que PROMs e os testes funcionais padronizados medem construtos diferentes da função: os PROMs, como o WOMAC, capturam a percepção do paciente sobre sua capacidade de realizar atividades diárias e o impacto da dor, enquanto os os testes funcionais padronizados, como o TUG, medem a capacidade máxima de desempenho em uma tarefa específica e cronometrada.

Outros autores também destacaram essas discrepâncias, afirmando que "a avaliação da melhora funcional após a ATJ requer tanto avaliações baseadas em desempenho quanto relatos do paciente" (Whatling et al., 2022). Os autores observaram que mudanças maiores são reportadas usando PROMs em comparação com medidas objetivas, sugerindo que a percepção subjetiva de melhora pode superestimar os ganhos funcionais reais.

5.4 A Utilidade dos Sensores Inerciais na Avaliação Pós-Operatória

Este estudo demonstrou a aplicabilidade e a utilidade clínica de um sensor inercial portátil (G-Walk®) para a avaliação instrumentalizada objetiva e quantitativa da marcha em um ambiente ambulatorial. A tecnologia permitiu a análise detalhada de múltiplos parâmetros espaço-temporais e cinemáticos, incluindo o índice de assimetria da marcha, que mostrou uma melhora progressiva ao longo do tempo em ambos os grupos (FB: 5,7% aos 6 meses para 2,3% aos 24 meses; MB: 5,9% aos 6 meses para 2,4% aos 24 meses), indicando uma normalização do padrão de marcha após a cirurgia. A capacidade de obter dados objetivos e reprodutíveis fora de um laboratório de marcha formal representa um avanço significativo para a prática clínica e a pesquisa em reabilitação.

A utilização de sensores vestíveis para análise de marcha após a ATJ é uma área em expansão, como destacado em revisão sistemática recente (Feng et al., 2023). Os autores revisaram as aplicações de sensores vestíveis para análise de marcha após ATJ, destacando a capacidade desses dispositivos de fornecer dados objetivos sobre variáveis cinemáticas que escalas clínicas convencionais poderiam negligenciar. Outros estudos também demonstraram a utilidade da avaliação objetiva da marcha usando sensores inerciais em pacientes com osteoartrose de joelho (Boekesteijn et al., 2022, Boekesteijn et al., 2024).

Esses dispositivos oferecem o potencial para um monitoramento mais frequente e em ambiente real da recuperação do paciente, permitindo a detecção precoce de padrões de marcha anormais e a individualização das intervenções de reabilitação. Autores estabeleceram que o TUG e o 2MWT possuem excelente confiabilidade teste-reteste em pacientes com ATJ (ICC do 2MWT: 0,97), com mudança mínima detectável no TUG de 2,27 segundos (Yuksel et al., 2017). A validação e a implementação de tais tecnologias, como realizado no presente estudo, são fundamentais para avançar em direção a uma avaliação mais precisa e personalizada dos resultados da ATJ.

6. CONSIDERAÇÕES FINAIS

6.1 Síntese Integradora dos Principais Achados

O presente estudo longitudinal e prospectivo, ao longo de 24 meses de acompanhamento, apresentou um conjunto de achados que, de forma integrada, aprimoram a compreensão sobre a recuperação funcional pós-artroplastia total do joelho (ATJ). A síntese dos resultados mais proeminentes pode ser sumarizada em quatro eixos centrais.

O primeiro eixo refere-se à aparente equivalência funcional entre os desenhos de prótese. O achado desta investigação foi a refutação da hipótese principal. No geral, não foram observadas diferenças estatisticamente significantes entre os implantes de platô móvel ultracongruente (MB) e de platô fixo póstero-estabilizado (FB) em nenhuma das variáveis funcionais objetivas (parâmetros de marcha, TUG, 2MWT) ou subjetivas (WOMAC, GLFS-10P) analisadas. Este resultado sugere que, no contexto da população estudada e no período avaliado, os dois desenhos de implante proporcionam resultados funcionais equivalentes em um seguimento de médio prazo.

O segundo eixo diz respeito à trajetória de recuperação não linear e declínio funcional tardio. A evolução funcional dos pacientes não seguiu uma trajetória de melhora linear e contínua. Observou-se um pico de desempenho funcional objetivo em torno de 12 meses de pós-operatório, particularmente no teste de caminhada de 2 minutos (2MWT). De forma notável, entre o 12º e o 24º mês, houve uma piora estatisticamente significante no desempenho do TUG, indicando um declínio na mobilidade funcional e agilidade, mesmo enquanto os pacientes continuavam a relatar melhora subjetiva.

O terceiro eixo aborda a dissociação entre medidas objetivas e subjetivas. O estudo revelou uma correlação consistentemente fraca entre as medidas de desempenho funcional objetivo e os desfechos relatados pelos pacientes (PROMs). A melhora contínua nos escores WOMAC e GLFS-10P, que indicam uma percepção positiva do paciente sobre sua dor e função, contrastou com a estagnação ou piora nos testes cronometrados. Este fenômeno evidencia que a percepção subjetiva de melhora pode não refletir necessariamente um ganho ou manutenção do desempenho físico quantificável.

O quarto eixo relaciona-se à melhora progressiva da simetria da marcha. A análise com o sensor inercial demonstrou que, independentemente do tipo de prótese, os pacientes apresentaram uma redução progressiva e significativa no índice de assimetria da marcha ao longo dos 24 meses. Este dado objetivo sugere uma gradual normalização do padrão de deambulação e uma melhor distribuição de carga entre os membros, um indicador positivo da recuperação neuromuscular após a ATJ.

6.2 Contribuições Científicas e Inovação

Este estudo pode contribuir para o conhecimento científico em diversos aspectos. Primeiramente, ao realizar um seguimento longitudinal de 24 meses, o estudo oferece uma perspectiva de médio prazo que vai além da maioria das investigações, que se concentram no primeiro ano pós-operatório. Essa janela temporal estendida foi necessária para a identificação do fenômeno do declínio funcional tardio, um achado de relevância clínica.

A inovação metodológica reside na avaliação funcional multimodal, integrando, de forma prospectiva e simultânea, testes de desempenho padronizados (TUG, 2MWT), desfechos relatados pelos pacientes (WOMAC, GLFS-10P) e uma análise cinemática instrumentalizada detalhada da marcha por meio de um sensor inercial portátil em ambiente ambulatorial. Essa abordagem permitiu comparar os implantes e avaliar a complexa relação entre o que o paciente sente (subjetivo) e o que ele de fato realiza (objetivo), revelando a importante dissociação entre esses domínios.

Adicionalmente, o estudo valida a aplicabilidade clínica de sensores inerciais como uma ferramenta objetiva, acessível e confiável para o monitoramento da qualidade da marcha fora do ambiente restrito de um laboratório, abrindo caminho para uma avaliação mais precisa e individualizada na prática ortopédica e de reabilitação cotidiana.

6.3 Implicações Clínicas

Os resultados deste estudo carregam implicações diretas para a prática clínica. A demonstrada equivalência funcional entre as próteses FB e MB sugere que a decisão sobre o tipo de implante pode ser flexibilizada, permitindo que cirurgiões considerem outros fatores, como custo-benefício, familiaridade com o sistema e características específicas do paciente, sem o receio de comprometer o resultado funcional em médio prazo.

O achado de um declínio funcional objetivo após o primeiro ano pós-operatório é um alerta para clínicos e pacientes. Ele desafia a noção de que a recuperação está completa após 12 meses e alerta a necessidade de um acompanhamento mais prolongado e da implementação de estratégias de reabilitação de manutenção. Programas de fortalecimento muscular, treino de equilíbrio e incentivo à atividade física regular para além do primeiro ano podem ser cruciais para preservar os ganhos funcionais e mitigar o declínio relacionado ao envelhecimento.

A dissociação entre as medidas objetivas e subjetivas enfatiza que a avaliação do sucesso da ATJ não deve se basear exclusivamente nos relatos dos pacientes. A incorporação de testes funcionais simples e rápidos, como o TUG, na rotina de acompanhamento pode identificar pacientes com declínio funcional subclínico, que, apesar de satisfeitos, podem estar em maior risco de quedas e perda de independência, permitindo uma intervenção precoce.

6.4 Limitações do Estudo

É necessário reconhecer as limitações desta pesquisa. Embora o cálculo amostral tenha sido realizado para garantir poder estatístico adequado (tamanho de efeito de 0,35, poder de 0,80, $\alpha = 0,05$), o número total de participantes ($n = 24$, sendo 12 por grupo) possa ser considerado modesto, a generalização dos resultados e a capacidade de detectar diferenças muito pequenas entre os grupos pode ser limitada. O delineamento como um estudo de centro único também pode introduzir vieses relacionados a protocolos cirúrgicos e de reabilitação específicos da instituição.

Outra possível limitação é a ausência de avaliação pré-operatória e de um grupo controle composto por indivíduos saudáveis pareados por idade, o que poderia fornecer um referencial para a magnitude do déficit funcional que persiste mesmo após uma ATJ bem-sucedida. Adicionalmente, embora o seguimento de 24 meses seja uma força do estudo, perdas de seguimento ocorreram, e fatores não controlados, como o nível de atividade física habitual dos pacientes e a adesão a programas de exercícios domiciliares, podem ter influenciado os desfechos a longo prazo. A realização da ATJ apenas em apenas um dos joelhos sem a caracterização de possível osteoartrose em joelho contralateral, comum nesta população, pode contribuir para a piora do desempenho dos participantes neste período.

A utilização de uma abordagem cirúrgica por uma equipe de cirurgiões, embora garanta homogeneidade metodológica, pode limitar a extrapolação dos resultados para pacientes operados por outros especialistas. Por fim, a avaliação da marcha foi realizada em ambiente controlado (ambulatorial), o que pode não refletir completamente o desempenho funcional dos pacientes em suas atividades de vida diária.

6.5 Perspectivas Futuras

Os achados e as limitações desta tese abrem diversas avenidas para futuras pesquisas. A replicação destes achados em estudos multicêntricos com amostras maiores é fundamental para confirmar a equivalência funcional dos implantes e a trajetória de recuperação observada. Investigações pré-operatórias e com maior seguimento (5 a 10 anos) são necessárias para determinar se o declínio funcional estabiliza ou progride ou surgem diferenças tardias entre os tipos de prótese.

Futuros estudos devem se aprofundar nas causas do declínio funcional tardio, investigando o papel da sarcopenia, da cinesiofobia (medo do movimento), dos níveis de atividade física e de fatores psicossociais. A utilização de sensores inerciais para monitorar a atividade e a qualidade da marcha dos pacientes em seu ambiente doméstico por longos períodos, com análise de atividades corriqueiramente realizada no cotidiano dos participantes, poderia fornecer insights valiosos sobre como os ganhos da reabilitação se traduzem no dia a dia.

Por fim, a pesquisa translacional focada no desenvolvimento e teste de intervenções de reabilitação de longo prazo, especificamente desenhadas para combater o declínio funcional após o primeiro ano de ATJ, representa um campo promissor e de grande necessidade clínica.

6.6 Conclusões Finais

Com base nos dados apresentados e discutidos ao longo desta tese, conclui-se que:

1. Os desenhos de prótese de joelho de platô móvel ultracongruente e de platô fixo póstero-estabilizado promovem resultados funcionais, de qualidade de vida e de parâmetros de marcha equivalentes em um seguimento de 24 meses, refutando a hipótese de superioridade do desenho de platô móvel.
2. A recuperação funcional após a ATJ atinge um platô em aproximadamente 12 meses, podendo apresentar um declínio subsequente em medidas objetivas de mobilidade, particularmente no teste TUG, um fenômeno que coexiste com a melhora contínua da percepção subjetiva do paciente.
3. Existe uma dissociação significativa entre medidas objetivas e subjetivas de função após a ATJ, reforçando a necessidade de uma abordagem avaliativa multimodal que não se baseie apenas nos relatos dos pacientes.
4. A utilização de sensor inercial portátil é uma ferramenta válida e clinicamente aplicável para a avaliação objetiva da marcha em ambiente ambulatorial,

permitindo a quantificação de parâmetros espaço-temporais e a detecção de assimetrias.

5 O acompanhamento clínico deve se estender para além do primeiro ano pós-operatório, com foco na manutenção da capacidade funcional através de estratégias de reabilitação contínuas, para garantir os benefícios da artroplastia a longo prazo e mitigar o declínio funcional relacionado ao envelhecimento.

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8. ANEXOS

8.1 Parecer de Aprovação do Comitê de Ética em Pesquisa (CEP/CONEP)

8.1.1 Aprovação CEP/CONEP - UniEvangélica

PARECER CONSUBSTANCIADO DO CEP

DADOS DA EMENDA

Título da Pesquisa: AVALIAÇÃO DA MARCHA, MOBILIDADE FUNCIONAL E QUALIDADE DE VIDA DOS PACIENTES SUBMETIDOS A ARTROPLASTIA DO JOELHO: UM ESTUDO TRANSVERSAL

Pesquisador: Claudia Santos Oliveira

Área Temática:

Versão: 3

CAAE: 52052421.9.0000.5076

Instituição Proponente: ASSOCIAÇÃO EDUCATIVA EVANGÉLICA

Patrocinador Principal: ASSOCIACAO EDUCATIVA EVANGELICA

DADOS DO PARECER

Número do Parecer: 5.550.628

Apresentação do Projeto:

Em conformidade com o número do parecer: 5.259.635

Objetivo da Pesquisa:

Objetivo geral

Avaliar os parâmetros espaço temporais da marcha, mobilidade funcional, capacidade funcional e a qualidade de vida dos pacientes submetidos a artroplastia primária de joelho entre dois tipos de prótese de joelho: póstero estabilizada de base de platô tibial fixa e prótese congruente de platô tibial rotatório para tratamento de artrose avançada do joelho.

Objetivos Específicos

a) Avaliar os parâmetros espaço temporais da marcha de pacientes com os dois tipos de próteses por meio do Walk Test aplicado com o sensor inercial;

b) Avaliar e comparar a mobilidade funcional de pacientes com os dois tipos de próteses por meio do Timed Up Go - TUG aplicado com o sensor inercial;

c) Avaliar a capacidade funcional dos pacientes por meio do 2 minute walk test - 2MWT (teste de caminhada de 2 minutos) com o sensor inercial;

d) Correlacionar a mobilidade funcional de pacientes submetidos a artroplastia de joelho por meio do Timed Up Go - TUG aplicado com o sensor inercial e o tempo de pós-operatório;

e) Correlacionar a mobilidade funcional de pacientes submetidos a artroplastia de joelho com o tipo de incisão cirúrgica Timed Up Go - TUG aplicado com o sensor inercial;
f) Comparar a qualidade de vida dos pacientes com os diferentes tipos de próteses por meio da aplicação do questionário Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).

Avaliação dos Riscos e Benefícios:
Em conformidade com o número do parecer: 5.259.635

Comentários e Considerações sobre a Pesquisa:
O pesquisador solicitou uma emenda para a inserção de membros à equipe de pesquisa onde foi inserido novos pesquisadores que estarão atuando nas coletas. Equipe da pesquisa: Mariana Mendes Trevizan Silva, Jackeline Batista Saldanha, Victoria Renata Evangelista De Freitas, Grazielly Nascimento Santos, Roberta Carneiro De Toledo, Giovana Lima Silva, Andrei Machado Viegas da Trindade, Lorraine Barbosa Cordeiro, Cicero Antônio Dos Santos Junior, Bruno Oliveira Silva.

Considerações sobre os Termos de apresentação obrigatória:
De acordo com as recomendações previstas pela RESOLUÇÃO CNS N. 466/2012 e demais complementares o protocolo permitiu a realização da análise ética. Todos os documentos listados abaixo foram analisados.

Recomendações:
Não se aplica.

Conclusões ou Pendências e Lista de Inadequações:
O protocolo de pesquisa encontra-se de acordo com a Resolução 466/12 do CNS, não apresentando nenhum óbice ético para sua execução.

Considerações Finais a critério do CEP:
Solicitamos ao pesquisador responsável o envio do RELATÓRIO FINAL a este CEP, via Plataforma Brasil, conforme cronograma de execução apresentado.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações	PB_INFORMAÇÕES_BÁSICAS_199021	27/07/2022		Aceito

Básicas do Projeto	_E1.pdf	17:26:12		Aceito
Outros	Carta_de_atendimento_as_pendencias.docx	28/11/2021 18:51:31	LORRAINE BARBOSA	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TERMO_DE_CONSENTIMENTO_LIVRE_ESCLARECIDO.docx	28/11/2021 18:50:35	LORRAINE BARBOSA CORDEIRO	Aceito
Projeto Detalhado / Brochura Investigador	projeto_detalhado.docx	28/11/2021 18:50:23	LORRAINE BARBOSA CORDEIRO	Aceito
Folha de Rosto	folha_De_Rosto_Assinada.pdf	24/09/2021 10:08:40	LORRAINE BARBOSA	Aceito
Outros	carta_de_justificativa_da_assinatura_da_carta_coparticipante.docx	24/09/2021 09:52:54	LORRAINE BARBOSA	Aceito
Outros	carta_coparticipante_assinada.pdf	24/09/2021 09:52:42	LORRAINE BARBOSA	Aceito
Outros	APENDICE_D_Ficha_de_Triagem.docx	13/09/2021 10:07:41	LORRAINE BARBOSA	Aceito
Outros	APENDICE_A_Declaracao_de_Coparticipante.docx	05/09/2021 21:34:21	LORRAINE BARBOSA	Aceito
Outros	ANEXO_A_WOMAC_para_Osteoartrose.docx	05/09/2021 21:32:44	LORRAINE BARBOSA	Aceito
Declaração de Pesquisadores	TERMO_DE_COMPROMETIMENTO.docx	05/09/2021 21:31:43	LORRAINE BARBOSA	Aceito
Outros	APENDICE_C_Termo_de_Autorizacao_de_Uso_de_Imagem.docx	05/09/2021 21:31:12	LORRAINE BARBOSA	Aceito
Orçamento	orcamento.docx	05/09/2021 21:23:36	LORRAINE BARBOSA	Aceito
Cronograma	CRONOGRAMA.docx	05/09/2021 21:22:45	LORRAINE BARBOSA	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

ANAPOLIS, 28 de Julho de 2022

Assinado por:
Constanza Thaise Xavier Silva
(Coordenador(a))

Endereço: Av. Universitária, Km 3,5
Bairro: Cidade Universitária **CEP:** 75.083-515
UF: GO **Município:** ANAPOLIS
Telefone: (62)3310-6736 **Fax:** (62)3310-6636 **E-mail:** cep@unievangelica.edu.br

8.1.2 Renovação aprovação CEP/CONEP – UniEvangélica

PARECER CONSUBSTANCIADO DO CEP

DADOS DA EMENDA

Título da Pesquisa: AVALIAÇÃO DA MARCHA, MOBILIDADE FUNCIONAL E QUALIDADE DE VIDA DOS PACIENTES SUBMETIDOS A ARTROPLASTIA DO JOELHO: UM ESTUDO TRANSVERSAL

Pesquisador: Claudia Santos Oliveira

Área Temática:

Versão: 4

CAAE: 52052421.9.0000.5076

Instituição Proponente: ASSOCIAÇÃO EDUCATIVA EVANGÉLICA

Patrocinador Principal: ASSOCIACAO EDUCATIVA EVANGELICA

DADOS DO PARECER

Número do Parecer: 6.775.127

Apresentação do Projeto:

Resumo

Contexto: A artroplastia de joelho é um dos principais tratamentos cirúrgico para as artroses avançadas, melhorando os aspectos da dor e funções motoras de indivíduos acometidos por esta patologia. O acompanhamento da evolução clínica pós-cirúrgica inclui testes funcionais e de autoavaliação, no entanto, muitas vezes a aplicação destes testes apresentam limitações, sejam de caráter operacional ou de custos, não auxiliando nos critérios de seleção e acompanhamento desta população. Objetivo: Avaliar os parâmetros espaço temporais da marcha, mobilidade funcional, capacidade funcional e a qualidade de vida dos pacientes submetidos a artroplastia primária de joelho entre dois tipos de prótese de joelho: póstero estabilizada de base de platô tibial fixa e prótese congruente de platô tibial rotatório para tratamento de artrose avançada do joelho. Materiais e método: Trata-se de um estudo transversal, a ser realizado após aprovação no comitê de ética onde a amostra será composta por 54 pacientes que foram submetidos a artroplastia total de joelho no Centro Estadual de Reabilitação e Readaptação Dr. Henrique Santillo ¿ CRER, onde serão avaliados por meio da aplicação do questionário WOMAC e das avaliações por meio dos testes: Walk Test, Timed Up Test e 2 minute walk test. Resultado: Espera-se que com base nos resultados, possa ter uma correlação positiva entre os parâmetros objetivos e subjetivos destes sujeitos e se há diferença

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Bairro: Cidade Universitária **CEP:** 75.083-515
UF: GO **Município:** ANAPOLIS
Telefone: (62)3310-6736 **Fax:** (62)3310-6636 **E-mail:** cep@unievangelica.edu.br

entre os tipos de próteses empregadas, auxiliando na tomada de decisão do tipo de prótese a ser indicada e melhorar o tempo de recuperação e reabilitação pós-operatória.
Palavras-chave: Artroplastia do joelho; Análise da Marcha; Mobilidade Funcional; Qualidade de Vida.

Objetivo da Pesquisa:
Objetivo Geral
Avaliar os parâmetros espaço temporais da marcha, mobilidade funcional, capacidade funcional e a qualidade de vida dos pacientes submetidos a artroplastia primária de joelho entre dois tipos de prótese de joelho: póstero estabilizada de base de platô tibial fixa e prótese congruente de platô tibial rotatório para tratamento de artrose avançada do joelho.

Objetivos Específicos
a) Avaliar os parâmetros espaço temporais da marcha de pacientes com os dois tipos de próteses por meio do Walk Test aplicado com o sensor inercial;
b) Avaliar e comparar a mobilidade funcional de pacientes com os dois tipos de próteses por meio do Timed Up Go - TUG aplicado com o sensor inercial;
c) Avaliar a capacidade funcional dos pacientes por meio do 2 minute walk test - 2MWT (teste de caminhada de 2 minutos) com o sensor inercial;
d) Correlacionar a mobilidade funcional de pacientes submetidos a artroplastia de joelho por meio do Timed Up Go - TUG aplicado com o sensor inercial e o tempo de pós-operatório;
e) Correlacionar a mobilidade funcional de pacientes submetidos a artroplastia de joelho com o tipo de incisão cirúrgica Timed Up Go - TUG aplicado com o sensor inercial;
f) Comparar a qualidade de vida dos pacientes com os diferentes tipos de próteses por meio da aplicação do questionário Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).

Avaliação dos Riscos e Benefícios:
Não se aplica.

Comentários e Considerações sobre a Pesquisa:
O pesquisador solicitou emenda para a participação de um novo integrante de pesquisa (Leonardo Pinheiro Rezende) na elaboração de um Follow-up a ser apresentado para obtenção do aperfeiçoamento profissional no programa de Iniciação Científica da Universidade Evangélica de Goiás (PIBIC).

Considerações sobre os Termos de apresentação obrigatória:
De acordo com as recomendações previstas pela RESOLUÇÃO CNS N.466/2012 e demais complementares o protocolo permitiu a realização da análise ética. Todos os documentos listados abaixo foram analisados.

Recomendações:
Não se aplica.

Conclusões ou Pendências e Lista de Inadequações:
O protocolo de pesquisa encontra-se de acordo com a Resolução 466/12 do CNS, não apresentando nenhum óbice ético para sua execução.

Considerações Finais a critério do CEP:
Solicitamos ao pesquisador responsável o envio do RELATÓRIO FINAL a este CEP, via Plataforma Brasil, conforme cronograma de execução apresentado.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_2225684_E2.pdf	29/03/2024 12:18:40		Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.odt	29/03/2024 12:16:33	LEONARDO PINHEIRO REZENDE	Aceito
Outros	Carta_de_atendimento_as_pendencias.docx	28/11/2021 18:51:31	LORRAINE BARBOSA CORDEIRO	Aceito
Projeto Detalhado / Brochura Investigador	projeto_detalhado.docx	28/11/2021 18:50:23	LORRAINE BARBOSA CORDEIRO	Aceito
Folha de Rosto	folha_De_Rosto_Assinada.pdf	24/09/2021 10:08:40	LORRAINE BARBOSA CORDEIRO	Aceito
Outros	carta_de_justificativa_da_assinatura_da_carta_coparticipante.docx	24/09/2021 09:52:54	LORRAINE BARBOSA CORDEIRO	Aceito
Outros	carta_coparticipante_assinada.pdf	24/09/2021 09:52:42	LORRAINE BARBOSA CORDEIRO	Aceito
Outros	APENDICE_D_Ficha_de_Triagem.docx	13/09/2021 10:07:41	LORRAINE BARBOSA CORDEIRO	Aceito

Outros	APENDICE_A_Declaracao_de_Coparticipante.docx	05/09/2021 21:34:21	LORRAINE BARBOSA CORDEIRO	Aceito
Outros	ANEXO_A_WOMAC_para_Osteoartrose.docx	05/09/2021 21:32:44	LORRAINE BARBOSA CORDEIRO	Aceito
Declaração de Pesquisadores	TERMO_DE_COMPROMETIMENTO.docx	05/09/2021 21:31:43	LORRAINE BARBOSA CORDEIRO	Aceito
Outros	APENDICE_C_Termo_de_Autorizacao_de_Uso_de_Imagem.docx	05/09/2021 21:31:12	LORRAINE BARBOSA CORDEIRO	Aceito
Orçamento	orcamento.docx	05/09/2021 21:23:36	LORRAINE BARBOSA CORDEIRO	Aceito
Cronograma	CRONOGRAMA.docx	05/09/2021 21:22:45	LORRAINE BARBOSA CORDEIRO	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

ANAPOLIS, 19 de Abril de 2024

Assinado por:
Constanza Thaise Xavier Silva
(Coordenador(a))

Endereço: Av. Universitária, Km 3,5
Bairro: Cidade Universitária **CEP:** 75.083-515
UF: GO **Município:** ANAPOLIS
Telefone: (62)3310-6736 **Fax:** (62)3310-6636 **E-mail:** cep@unievangelica.edu.br

8.1.3 Declaração de Instituição Coparticipante

Declaramos ciência quanto à realização da pesquisa intitulada "AVALIAÇÃO DA MARCHA, MOBILIDADE FUNCIONAL E QUALIDADE DE VIDA DOS PACIENTES SUBMETIDOS A ARTROPLASTIA DO JOELHO: UM ESTUDO TRANSVERSAL", realizada por Andrei Machado Viegas da Trindade, telefone de contato 62 98142-2255, matriculado no curso de DOUTORADO em Ciências da Saúde da Faculdade de Ciências Médicas da Santa Casa de São Paulo - FCMSCSP, sob a orientação da professora Dra. Cláudia Santos Oliveira, a fim de desenvolver o DOUTORADO, para obtenção do título de DOUTOR, sendo está uma das exigências do programa. No entanto, os pesquisadores garantem que as informações e dados coletados serão utilizados e guardados, exclusivamente para fins previstos no protocolo desta pesquisa. Avaliar os parâmetros espaço temporais da marcha, mobilidade funcional, capacidade funcional e a qualidade de vida dos pacientes submetidos a artroplastia primária de joelho entre dois tipos de prótese de joelho: póstero estabilizada de base de platô tibial fixa e prótese congruente de platô tibial rotatório para tratamento de artrose avançada do joelho, fazendo-se necessário a coleta de dados nesta instituição, pois configura importante etapa de elaboração da pesquisa. Para a coleta de dados haverá a avaliação de pacientes submetidos a artroplastia total de joelho para tratamento de artrose avançada nos joelhos de acordo com os critérios de inclusão sendo: a) submetidos a artroplastia primária do joelho unilateral; b) com quadro de artrose avançada do joelho com classificação Kellgren and Lawrence ≥4; c) idade 50 a 80 anos. O nome do participante do questionário será ocultado, garantindo o sigilo nominal da pessoa. A princípio esta pesquisa acarreta baixos riscos aos participantes, porém se tratando de uma pesquisa multidisciplinar com a ortopedia e fisioterapia os participantes poderão apresentar algum desconforto emocional, fadiga muscular, quedas e ou câimbras no momento da avaliação, por exemplo. Devidos aos procedimentos de avaliação da área da ortopedia e fisioterapia não serem invasivos, as medidas protetivas adotadas na minimização dos riscos decorrem de favorecer os sujeitos um momento de contato e reconhecimento com o laboratório e profissionais que o atenderão no sentido de familiarização com o ambiente. As avaliações serão realizadas por profissionais da área de ortopedia e fisioterapia, sendo que nas avaliações motoras os participantes serão acompanhados por ao menos um voluntário e o profissional que permanecerão posicionados ao seu lado por toda avaliação. Diante do cenário pandêmico que vivemos, com o risco eminente de contaminação por meio do novo coronavírus (SARS-CoV-2), algumas medidas de prevenção tornam-se de grande relevância, visando minimizar os riscos inerentes à pandemia por COVID 19, as medidas de prevenção adotadas seguindo o protocolo de biossegurança da instituição CRER onde será realizada a coleta, tais como: no momento do agendamento das coletas será repassado aos participantes da pesquisa informações referentes as medidas de prevenção ao COVID-19; sendo que caso o mesmo apresente quais quer sintomas gripal comunique aos pesquisadores e não compareça a coleta agendada. As medidas de prevenção adotadas: todas as macas e superfícies serão devidamente higienizados antes e após as coletas, o consultório ocupado será limpo a cada 1 hora bem como de todos os instrumentos que serão utilizados durante o processo de avaliação; todos os participantes da pesquisa serão instruídos a realizar a higienização das mãos antes, durante e após a coleta; álcool em gel será disponibilizado em todo local; a coleta será realizada em local arejado e ventilado; todos os pesquisadores envolvidos estarão devidamente aparamentados com os equipamentos de proteção individual necessários, como máscaras N-95, capotes e luvas descartáveis; será exigido o uso de máscara por todos os participantes da pesquisa durante todo o tempo, caso haja alguma mudança de restrição nos protocolos municipais, estaduais e no protocolo de segurança do CRER serão interrompidas as avaliações. O benefício direto será o feedback que os participantes e responsáveis receberão após a pesquisa dos questionários funcionais e observações voltados ao processo de reabilitação e resultados pós-operatórios e avaliações completas de equilíbrio e marcha com equipamentos de última geração no campo da reabilitação funcional e poderão utilizar no auxílio ao comportamento e na compreensão do transtorno em intervenções mais eficazes. O benefício indireto é que a partir destas avaliações teremos embasamento científico para o desenvolvimento de estudos futuros verificando efeitos de intervenções mais específicas apropriadas ao desenvolvimento e aperfeiçoamento dos desenhos de próteses e técnicas cirúrgicas mais eficazes e com melhor resultados pós-operatório para o tratamento cirúrgico dos pacientes portadores de artroses avançadas do joelho. Declaramos que a autorização para realização da pesquisa acima descrita será mediante a apresentação de parecer ético aprovado emitido pelo CEP da Instituição Proponente, nos termos da Resolução CNS nº. 466/12. Esta instituição está ciente de suas corresponsabilidades como instituição coparticipante do presente projeto de pesquisa de seu compromisso no resguardo da segurança e bem-estar dos participantes de pesquisa nela recrutados, dispondo de infraestrutura necessária para a garantia de segurança e bem-estar.

Anápolis,_______de______________________________de________.

____

Assinatura e carimbo do responsável institucional.

Goiânia, 31 de agosto de 2021.

DECLARAÇÃO DE AUTORIZAÇÃO PARA REALIZAR PESQUISA

A Associação de Gestão, Inovação e Resultados em Saúde - AGIR, declara para os devidos fins conhecer e cumprir as Resoluções Éticas Brasileiras, em especial a Resolução nº 466/12 do Conselho Nacional de Saúde.

Declara que estamos cientes e autorizamos a realização, na Unidade CRER, do projeto de pesquisa intitulado, **"Avaliação da marcha, mobilidade funcional e qualidade de vida dos pacientes submetidos a artroplastia do joelho: um estudo transversal"**, sob responsabilidade do pesquisador **Andrei Machado Viegas Da Trindade**. Essa instituição está ciente de suas corresponsabilidades como instituição coparticipante do projeto supracitado e de seu compromisso e responsabilidade pela guarda, segurança e bem-estar dos sujeitos de pesquisa nela recrutados e seus dados, dispondo de infraestrutura necessária para essa garantia.

____

Ciro Bruno Silveira Costa

Diretor Técnico do CRER

____

Helca de Sousa Nascimento

Diretora de Ensino e Desenvolvimento da AGIR

____

Lucas Paula da Silva

Superintendente Executivo da AGIR

Documento assinado eletronicamente por Ciro Bruno Silveira Costa , DIT - DIRETORIA TECNICA - CRER em 31/08/2021, as 15:33:24, conforme horário oficial de Brasília.

Documento assinado eletronicamente por Helca De Sousa Nascimento , DCED - DIRETORIA DE ENSINO E DESENVOLVIMENTO - CED em 01/09/2021, as 15:24:28, conforme horário oficial de Brasília.

Documento assinado eletronicamente por Lucas Paula Da Silva , SE - SUPERINTENDENCIA EXECUTIVA - AGIR em 03/09/2021, as 11:26:44, conforme horário oficial de Brasília.

Processo 20210001.04536
A autenticidade do documento pode ser conferida no site
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TERMO DE CONSENTIMENTO DE USO DE DADOS

AUTORIZAÇÃO PARA MANUSEIO DE DADOS/PRONTUÁRIOS

Declaro ter lido e concordar com o projeto " **Avaliação da marcha, mobilidade funcional e qualidade de vida dos pacientes submetidos a artroplastia do joelho: um estudo transversal",** de responsabilidade do pesquisador **Andrei Machado Viegas Da Trindade** e declaro conhecer e cumprir as Resoluções Éticas Brasileiras, em especial, a resolução 466/12 do Conselho Nacional de Saúde. Esta Instituição está ciente de suas responsabilidades como instituição coparticipante do presente projeto de pesquisa e de seu cumprimento no resguardo da segurança e do bem-estar de sujeitos de pesquisa nela recrutados, dispondo de infraestrutura necessária para a garantia de tal segurança e bem-estar. **Estou ciente e autorizo o acesso aos prontuários para coleta de dados**, salvo que a execução deste projeto dependerá da aprovação do mesmo pelo CEP da instituição proponente, mediante parecer ético consubstanciado e declaração de aprovação.

Goiânia, 31 de agosto de 2021.

Ciro Bruno Silveira Costa

Diretor Técnico do CRER

Helca de Sousa Nascimento

Diretora de Ensino e Desenvolvimento da AGIR

Lucas Paula da Silva

Superintendente Executivo da AGIR

-
Documento assinado eletronicamente por Ciro Bruno Silveira Costa , DIT - DIRETORIA TECNICA - CRER em 31/08/2021, as 15:33:26, conforme horário oficial de Brasília.

Av. Vereador José Monteiro, Nº 1655,
St Negrão de Lima - Goiânia - Goiás
CEP: 74653-230

Fone: 62 3232-3232 / 3232-3000
crer@crer.org.br

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8.2 Termo de Consentimento Livre e Esclarecido (TCLE)

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO (TCLE)

AVALIAÇÃO E EVOLUÇÃO DA MARCHA, MOBILIDADE FUNCIONAL E QUALIDADE DE VIDA DOS PACIENTES SUBMETIDOS A ARTROPLASTIA DO JOELHO

Prezado participante, "Você está sendo convidado(a) para participar da pesquisa AVALIAÇÃO E EVOLUÇÃO DA MARCHA, MOBILIDADE FUNCIONAL E QUALIDADE DE VIDA DOS PACIENTES SUBMETIDOS A ARTROPLASTIA DO JOELHO". "Desenvolvida por Andrei Machado Viegas da Trindade, telefone de contato (62) 9090 98142-2255, matriculado no curso de DOUTORADO em Ciências da Saúde da Faculdade de Ciências Médicas da Santa Casa de São Paulo - FCMSCSP, sob a orientação da Professora Dra. Cláudia Santos Oliveira, a fim de desenvolver o Doutorado, para obtenção do título de Doutor, sendo está uma das exigências do curso."

O objetivo central do estudo é: Avaliar os parâmetros espaço temporais da marcha, mobilidade funcional, capacidade funcional e a qualidade de vida dos pacientes submetidos a artroplastia primária de joelho entre dois tipos de prótese de joelho: póstero estabilizada de base de platô tibial fixa e prótese congruente de platô tibial móvel para tratamento de artrose avançada do joelho. "O convite a sua participação se deve ao interesse dos pesquisadores em investigar a associação entre a autoavaliação dos resultados funcionais pós operatórios de artroplastia total de joelho e sua correlação com testes clínicos e parâmetros laboratoriais da função pós-operatória dos pacientes submetidos a artroplastia de joelho nos quesitos de atividade física diária, equilíbrio e padrão de marcha; por meio da assinatura de um Termo de Consentimento Livre e Esclarecido, onde irão declarar ter ciência de que o procedimento ao qual serão submetidos é voluntário, gratuito e experimental, de acordo com os critérios inclusão que são: a) submetidos a artroplastia primária do joelho unilateral; b) com quadro de artrose avançada do joelho com classificação Kellgren and Lawrence ≥4; c) idade 50 a 80 anos; d) cirurgia com a prótese póstero estabilizada de base de platô tibial fixa sem a preservação do ligamento cruzado posterior; e) cirurgia com a prótese congruente de platô tibial móvel sem a preservação do ligamento cruzado posterior e) concordar com a sua participação no estudo por meio da assinatura do Termo de Consentimento Livre e Esclarecido, você está sendo convidado a participar desta pesquisa”

“Sua participação é voluntária, isto é, ela não é obrigatória e você tem plena autonomia para decidir se quer ou não participar, bem como retirar sua participação a qualquer momento. Você não será penalizado de nenhuma maneira caso decida não consentir sua participação, ou desistir da mesma. Contudo, ela é muito importante para a execução da pesquisa. Se você morar longe do local de coleta que será no CRER- Centro Estadual de Reabilitação e Readaptação Dr Henrique Santillo, nós daremos um suporte de custeamento suficiente para transporte, para você e para um acompanhante também.”

“Serão garantidas a confidencialidade e a privacidade das informações por você prestadas, todos os dados obtidos referentes às avaliações ficarão sobre responsabilidade do pesquisador responsável e colaboradores destinados estritamente ao uso acadêmico, qualquer dado que possa identificá-lo será omitido na divulgação dos resultados da pesquisa, portanto seu nome e nenhuma característica que possa identificá-lo (a) não constará em nenhuma das nossas publicações e o material das coletas tem seu armazenamento em local próprio e seguro o presente estudo obedece às Diretrizes e Normas Regulamentadoras de pesquisa envolvendo seres humanos, formuladas pelo Conselho Nacional de Saúde, Ministério da Saúde, estabelecidas em outubro de 1996 e atualizadas na resolução 466 em 2012, no Brasil. Para lhe assegurar a confidencialidade e privacidade nesta pesquisa, assim que realizar a triagem, receberá um código numérico ao qual vai estar presente em todas as suas fichas e avaliações, assim no decorrer da análise dos dados não vamos nos referir a você pelo nome ou característica e sim pelo código. Os dados serão armazenados de forma física e digital visto que os dados que forem coletados de forma manual em papel sertão digitalizados armazenados por cinco anos conforme a Resolução 466/12 após este período será descartado conforme a recomendação os arquivos físicos serão colocados em uma fragmentadora de papel e os arquivos digitalizados excluídos de forma permanente." A qualquer momento, durante a pesquisa, ou posteriormente, você poderá solicitar do pesquisador informações sobre sua participação e/ou sobre a pesquisa, o que poderá ser feito através dos meios de contato explicitados neste Termo. O projeto será desenvolvido no Centro Estadual de Reabilitação e Readaptação Dr. Henrique Santillo – CRER, Universidade Evangélica de Goiás – UniEVANGÉLICA e Pós-Graduação em Ciências da Saúde da Faculdade de Ciências Médicas da Santa Casa de São Paulo - FCMSCSP, o qual possui infraestrutura e pessoal acadêmico profissional necessário para realização do mesmo em sala apropriada e com todos os equipamentos necessários. O Centro Estadual de Reabilitação e Readaptação Dr. Henrique Santillo – CRER, Universidade Evangélica de Goiás – UniEVANGÉLICA e a Pós-Graduação em Ciências da Saúde da Faculdade de Ciências Médicas da Santa Casa de São Paulo - FCMSCSP possuem capacidade técnica e de infraestrutura, assim como apoio institucional suficiente para garantir a realização do projeto. Para este projeto será utilizado na instituição o ambulatório para triagem e coleta dos dados demográficos e da autoavaliação a qual você terá contato com o médico para aplicação do instrumento: Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) e a versão curta do questionário de 25 questões da Geriatric Locomotive Function Scale-Portuguese (GLFS-10P) e para análise motora com um fisioterapeuta será solicitado a você e que traga roupas confortáveis para: Avaliação da mobilidade funcional por meio o Timed Up Go test (TUG); Avaliação dos parâmetros espaço temporais da marcha por meio do Walk Test com o sensor inercial; Avaliação de capacidade funcional com o 2 minute walk test (2MWT). O tempo de duração das avaliações subjetivas é de aproximadamente vinte minutos, e das avaliações motoras de aproximadamente quarenta minutos sendo que varia de acordo com a colaboração do participante sendo um tempo menor ou maior. As entrevistas serão transcritas e armazenadas no computador institucional do laboratório em pasta específica da pesquisa a qual para ter acesso será necessário senha que somente terão acesso às mesmas o pesquisador e sua orientadora. Ao final da pesquisa, todo material será mantido em arquivo, por pelo menos 5 anos, conforme Resolução 466/12 e orientações do CEP/UniEVANGÉLICA. O benefício direto será o feedback em formato de relatório de todos os dados avaliados poderão ser entregues para o médico/ fisioterapeuta equipe que o acompanha gerando embasamento para as intervenções caso sejam necessárias, que os participantes e responsáveis receberão após a pesquisa dos questionários funcionais e observações voltados ao processo de reabilitação e resultados pós-operatórios e avaliação da marcha, da mobilidade funcional, da capacidade funcional e qualidade de vida com equipamentos de última geração no campo da reabilitação funcional e poderão utilizar no auxílio ao comportamento e na compreensão do transtorno em intervenções mais eficazes. O benefício indireto é que a partir destas avaliações teremos embasamento científico para o desenvolvimento de estudos futuros verificando efeitos de intervenções mais específicas apropriadas ao desenvolvimento e aperfeiçoamento dos desenhos de próteses e técnicas cirúrgicas mais eficazes e com melhor resultados pós-operatório para o tratamento cirúrgico dos pacientes portadores de artroses avançadas do joelho, relatórios individuais para os participantes, artigos científicos e na dissertação. ______________________________

____

Assinatura do Pesquisador Responsável – Membro do Corpo Docente da Universidade Evangélica de Goiás – UniEVANGÉLICA e do Pós-Graduação em Ciências da Saúde da Faculdade de Ciências Médicas da Santa Casa de São Paulo - FCMSCSP.

Contato com o(a) pesquisador(a) responsável: Cláudia Santos Oliveira, telefone: (11) 9090 99171- 6844. Endereço: Avenida Universitária, Km 3,5 Cidade Universitária – Anápolis/GO CEP: 75083-580

CONSENTIMENTO DA PARTICIPAÇÃO DA PESSOA COMO PARTICIPANTE DE PESQUISA

Eu,______________________________________ CPF nº __________________, abaixo assinado, concordo voluntariamente em participar do estudo acima descrito, como participante. Declaro ter sido devidamente informado e esclarecido pelo pesquisador ______________________________________ sobre os objetivos da pesquisa, os procedimentos nela envolvidos, assim como os possíveis riscos e benefícios envolvidos na minha participação. Foi me dada a oportunidade de fazer perguntas e recebi telefones para entrar em contato, a cobrar, caso tenha dúvidas. Fui orientado para entrar em contato com o CEP - UniEVANGÉLICA (telefone 3310-6736), caso me sinta lesado ou prejudicado. Foi-me garantido que não sou obrigado a participar da pesquisa e posso desistir a qualquer momento, sem qualquer penalidade. Recebi uma via deste documento.

Anápolis, ___ de ___________ de 20_____,

____

Assinatura do participante da pesquisa Testemunhas (não ligadas à equipe de pesquisadores):

Nome:_________________________Assinatura:_________________________

Nome:_________________________Assinatura:_________________________

Em caso de dúvida quanto à condução ética do estudo, entre em contato com o Comitê de Ética em Pesquisa da UniEVANGÉLICA: Tel e Fax - (0XX) 62- 33106736 E-mail: cep@unievangelica.edu.br

8.3 Ficha de Coleta de Dados Clínicos e Demográficos

FICHA DE TRIAGEM

Identificação:____
Data de nascimento:____/___/_____ Idade:______ Sexo: (__) Feminino (__) Masculino
Altura:________ Peso:_________ IMC:__________
Telefone: (___) _______________ Estado civil: ______________________________
Endereço:____

Histórico cirúrgico

Data da cirurgia realizada:___________________
Lateralidade da artroplastia total primária do joelho: (__) Direito (__) Esquerdo
Artroplastia total primária do joelho contralateral: (__) Sim (__) Não

Especificação de acesso cirúrgico: (__) Transquadricipital (__) Subvastomedial

Especificação do desenho e modelo de implante da prótese de joelho utilizada:
(__) póstero estabilizada de base de platô tibial fixa sem a preservação do ligamento cruzado posterior.
(__) prótese congruente de platô tibial móvel sem a preservação do ligamento cruzado posterior.

8.4 Questionário WOMAC (Western Ontario McMaster Universities Index)

ÍNDICE WOMAC PARA OSTEOARTROSE

ANÔNIMO E CONFIDENCIAL

Toda informação que você fornecer será estritamente confidencial e somente apresentada como parte de um relatório estatístico. Nenhuma informação que possa associar uma pessoa em particular a uma resposta geral ou específica será publicada.

Se você tem qualquer dúvida ou comentário sobre este estudo, sinta-se a vontade para escrever ou telefonar: ___________________________________

INSTRUÇÕES PARA OS PACIENTES

Nas seções A, B e C as questões serão feitas no seguinte formato, e você deverá responder marcando um "X" nos quadrados abaixo.

NOTA:

1. Se você colocar o "X" no quadrado da esquerda, ex.:

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

Você está indicando que não sente qualquer dor.

2. Se você colocar o "X" no último quadrado da direita, ex.:

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

Você está indicando que sua dor é muito forte.

3. Favor observe:

a. Que quanto mais para a direita você colocar o "X", mais dor você está sentindo.
b. Que quanto mais para a esquerda você colocar o "X", menos dor você está sentindo
c. Favor não colocar o "X" fora dos quadrados.

Você será solicitado a indicar neste tipo de escala a quantidade de dor, rigidez ou incapacidade física que você está sentindo. Favor lembrar que quanto mais para a direita você marcar o "X", maior dor, rigidez ou incapacidade física você está sentindo.

SEÇÃO A

INSTRUÇÕES PARA OS PACIENTES

A questão abaixo refere-se a intensidade da dor que você geralmente sente devido a artrose em seu joelho. Para cada situação, por favor marque a intensidade da dor sentida nas últimas 72 horas (favor marcar suas respostas com um "X").

Questão:

Quanta dor você tem?

1- Caminhando numa superfície plana.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

2- Subindo ou descendo escadas.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

3- A noite, deitado na cama.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

4- Sentando ou deitando.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

5- Ficando em pé.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

SEÇÃO B
INSTRUÇÕES PARA OS PACIENTES

As seguintes questões referem-se a intensidade de rigidez articular (não a dor) que você vem sentindo em seu joelho nas últimas 72 horas. Rigidez é uma sensação de restrição ou lentidão na maneira como você move suas articulações (favor marcar suas respostas com um "X")

1- Qual a intensidade de sua rigidez logo após acordar de manhã?

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

2- Qual a intensidade da rigidez após sentar-se, deitar-se ou descansar durante o dia?

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

SEÇÃO C
INSTRUÇÕES PARA OS PACIENTES

As seguintes questões referem-se à sua atividade física. Isto quer dizer, sua habilidade para locomover-se e para cuidar-se. Para cada uma das seguintes atividades, por favor marque o grau da dificuldade que você vem sentindo nas últimas 72 horas devido a artrose em seu joelho (favor marcar suas respostas com um "X").

Questão: Qual é o grau da dificuldade que você tem :

1- Descendo escadas.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

2- Subindo escadas.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

3- Levantando-se de uma cadeira.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

4- Ficando em pé.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

5- Curvando-se para tocar o chão.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

6- Caminhando no plano.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

7- Entrando ou saindo do carro.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

8- Fazendo compras.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

9- Colocando as meias / meias-calça.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

10- Levantando da cama.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

11- Tirando as meias / meias-calça.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

12- Deitando na cama.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

13- Entrando ou saindo do banho.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

14- Sentando-se.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

15- Sentando-se ou levantando-se do vaso sanitário.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito Forte ☐

16- Fazendo tarefas domésticas pesadas.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

17- Fazendo tarefas domésticas leves.

Nenhuma ☐ Leve ☐ Moderada ☐ Forte ☐ Muito forte ☐

8.5 Escala GLFS-10P (short version of the 25-question Geriatric Locomotive Function Scale-Portuguese)

Appendix 1. Short version of the 25-question Geriatric Locomotive Function Scale-Portuguese (GLFS 25-P) supplementary material

ESCALA GERIÁTRICA DA FUNÇÃO LOCOMOTORA DE 10 ITENS – GLFS 10-P

As perguntas a seguir se referem à sua condição de saúde e atividades de vida diária, relacionados a suas costas, membros inferiores e superiores. Por favor, responda considerando sua condição no último mês:

	0 ponto	***1 ponto***	***2 pontos***	***3 pontos***	***4 pontos***
1) Até que ponto tem sido difícil praticar atividades esportivas?	*Sem dificuldade*	*Pouca dificuldade*	*Moderada dificuldade*	*Muita dificuldade*	*Extrema dificuldade*
2) Até que ponto tem sido difícil andar rápido?	*Sem dificuldade*	*Pouca dificuldade*	*Moderada dificuldade*	*Muita dificuldade*	*Extrema dificuldade*
3) Quanto você consegue andar sem descansar?	*Mais de 2-3Km*	*Aproximadamente 1Km*	*Aproximadamente 300m*	*Aproximadamente 100m*	*Aproximadamente 10m*
4) Até que ponto tem sido difícil realizar as tarefas pesadas do lar?	*Sem dificuldade*	*Pouca dificuldade*	*Moderada dificuldade*	*Muita dificuldade*	*Extrema dificuldade*
5) Até que ponto tem sido difícil usar o banheiro?	*Sem dificuldade*	*Pouca dificuldade*	*Moderada dificuldade*	*Muita dificuldade*	*Extrema dificuldade*
6) Até que ponto tem sido difícil levantar da cama ou deitar?	*Sem dificuldade*	*Pouca dificuldade*	*Moderada dificuldade*	*Muita dificuldade*	*Extrema dificuldade*
7) Até que ponto tem sido difícil caminhar dentro de casa?	*Sem dificuldade*	*Pouca dificuldade*	*Moderada dificuldade*	*Muita dificuldade*	*Extrema dificuldade*
8) Até que ponto tem sido difícil levantar da cadeira?	*Sem dificuldade*	*Pouca dificuldade*	*Moderada dificuldade*	*Muita dificuldade*	*Extrema dificuldade*
9) Você já se sentiu com medo de não poder andar no futuro?	*Nunca*	*Quase nunca*	*Às vezes*	*Quase sempre*	*Sempre*
10) Você já se sentiu com medo de cair dentro de casa?	*Nunca*	*Quase nunca*	*Às vezes*	*Quase sempre*	*Sempre*

8.6 Anexo 6 - Artigos publicados

8.6.1 Use of Sensors in Rehabilitation of Patients Undergoing Knee Arthroplasty: A Systematic Review

Trindade AMV, Rezende LP, Morais ATA, Marinho MB, Sandes EB, Machado MM, Parreira RB, Cimolin V, Santili C, Oliveira CS. Use of sensors in rehabilitation of patients undergoing knee arthroplasty: a systematic review. J Adv Med Med Res. 2025;37(12):459-75. doi: 10.9734/jammr/2025/v37i126031

Journal of Advances in Medicine and Medical Research – Qualis Capes A3

Nesta revisão sistemática sobre o uso de sensores na reabilitação de pacientes submetidos à artroplastia de joelho, foram incluídos 21 estudos transversais, totalizando 758 pacientes pós-artroplastia total de joelho e aproximadamente 210 controles sadios. Os trabalhos utilizaram, em sua maioria, unidades de medida inercial (IMUs) posicionadas principalmente na pelve/coluna lombar ou em múltiplos segmentos dos membros inferiores, em protocolos de marcha que variaram de percursos curtos em solo (6–40 m) e esteira a monitorização contínua em ambientes domiciliares. Os principais desfechos analisados foram parâmetros espaciotemporais (velocidade, cadência, comprimento de passo, tempos de apoio e balanço) e cinemáticos (amplitude de movimento do joelho, movimentos de pelve e tronco). De forma consistente, os estudos demonstraram déficits espaciotemporais persistentes e alterações cinemáticas após a artroplastia, quando comparados a controles, ao mesmo tempo em que confirmaram boa confiabilidade (ICC geralmente >0,85) e acurácia (erro angular

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Use of Sensors in Rehabilitation of Patients Undergoing Knee Arthroplasty: A Systematic Review

Andrei Machado Viegas da Trindade [a,b,c], Leonardo Pinheiro Rezende [d*], Adryan Tyrone Alves de Morais [d], Mariana Bessa Marinho [d], Enzo Boaventura Sandes [d], Matheus Maciel Machado [d], Rodolfo Borges Parreira [b], Verônica Cimolin [e], Claudio Santili [b] and Cláudia Santos Oliveira [b,c]

[a] *Department of Orthopedics Surgery, Municipal Hospital of Aparecida de Goiânia (HMAP), Aparecida de Goiânia 74936-600, Brazil.*
[b] *Health Sciences Program, Santa Casa de São Paulo School of Medical Sciences, São Paulo 01221-020, Brazil.*
[c] *Faculty of Medicine, University Evangelica of Goiás (UniEVANGÉLICA), Anápolis 75083-515, Brazil.*
[d] *Medical Student, Evangelical University of Goiás (UniEVANGÉLICA), Anápolis, Brazil.*
[e] *Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy.*

This work was carried out in collaboration among all authors. Authors AMVDT and LPR conceived and designed the systematic review, developed the search strategy, drafted the protocol, and coordinated the review workflow. Authors ATADM and MBM conducted title/abstract screening and full-text eligibility assessment. Authors EBS and MMM performed data extraction and organized the study characteristics tables. Authors RBP and LPR assessed methodological quality and risk of bias and resolved discrepancies. Authors AMVDT and VC contributed to the methodological and clinical interpretation of the findings and supported the critical appraisal of the sensor-based outcomes. Author CSO supervised the project, provided senior oversight of the methodology and interpretation, and critically revised the manuscript for important intellectual content. Authors AMVDT and LPR wrote the first draft of the manuscript, and all authors contributed to manuscript review and editing. All authors read and approved the final manuscript.

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Corresponding author: E-mail: leonardorezende4@gmail.com;

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This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/149757

Systematic Review Article

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ABSTRACT

Aims: To characterize the use of inertial sensors for assessing mobility, function, and gait in patients undergoing unilateral knee arthroplasty for advanced osteoarthritis.
Study Design: Systematic review.
Place and Duration of Study: Searches were performed in PubMed, Embase, Scopus and Web of Science databases with no restrictions on date, language, or disease severity. Study selection was completed in 2025. Searches were last performed in 2025.
Methodology: This review was registered with PROSPERO (CRD420251002284) and conducted according to PRISMA guidelines. Two independent reviewers screened titles, abstracts, and full texts using predefined inclusion and exclusion criteria. Risk of bias was assessed using a 10-item adapted Downs & Black scale. Data on study populations, experimental protocols, and gait parameters were extracted and synthesized descriptively.
Results: Twenty-one cross-sectional studies were included, comprising 758 patients post-TKA and approximately 210 healthy controls. Inertial sensors ranged from 1 to 15 units, most placed on the lower back or pelvis. Walking protocols spanned 6–40 m courses, treadmill tests, oval circuits, and "free-living" monitoring. The primary parameters collected were spatiotemporal (speed, cadence, step length, phase durations) and kinematic (knee joint angles and pelvis/trunk movements). Studies demonstrated good reliability (ICC > 0.85) and accuracy (< 5° angular error). None explicitly investigated differences by prosthesis type. Findings reveal persistent spatiotemporal deficits and kinematic alterations following TKA.
Conclusion: Wearable inertial sensors appear to be valid and feasible tools for capturing mobility, function, and gait outcomes after knee arthroplasty. However, substantial methodological heterogeneity (e.g., sensor placement, sampling rates, assessment protocols, and outcome definitions) limits cross-study comparability and precluded meta-analysis. Standardization of protocols and improved reporting, together with higher-quality comparative studies (including evaluation of implant design effects), are priorities to support clinical implementation.

Keywords: Inertial measurement unit; gait analysis; rehabilitation; systematic review; total knee arthroplasty; wearable sensors.

ABBREVIATIONS

6MWT	*: 6-Minute Walk Test*
AP-UKA	*: Polyethylene Prosthetic Tibial Component*
CWS	*: Comfortable Walking Speed*
HC	*: Healthy Controls*
ICC	*: Intraclass Correlation Coefficients*
IMUs	*: Inertial Measurement Units*
MB-UKA	*: Metal Prosthetic Tibial Component UKA*
NAPE	*: Normalized Absolute Percentage Error*
OA	*: Osteoarthritis*
PRISMA	*: Preferred Reporting Items for Systematic Reviews and Meta-Analyses*
PROMs	*: Patient-Reported Outcome Measures*
PT	*: Physiotherapy*
ROM	*: Range of Motion*

Sen	*: Sample Entropy*
THA	*: Total Hip Arthroplasty*
TKA	*: Total Knee Arthroplasty*
TKR	*: Total Knee Replacement*
TUGT (or TUG)	*: Timed Up-and-Go Test*
UKA	*: Unicompartmental Knee Arthroplasty*

1. INTRODUCTION

Osteoarthritis (OA) is a chronic degenerative joint disease that represents one of the leading causes of disability in adults worldwide, with the knee being the most affected joint. The condition is characterized by the progressive degradation of articular cartilage and underlying subchondral bone, leading to debilitating pain, loss of function, and a significant reduction in quality of life (Cui, Li, & Chen, 2020; Giorgino et al., 2023; Schulze et al., 2012). The global prevalence of OA has increased substantially, driven by factors such as population aging and rising rates of obesity, placing a considerable burden on healthcare systems and economies (Li et al., 2024).

For patients with advanced, end-stage knee OA, where conservative treatments such as physical therapy and pharmacological interventions have failed to provide adequate relief, total knee arthroplasty (TKA) is the definitive surgical treatment. TKA is a highly effective procedure aimed at alleviating pain, restoring joint function, and improving the overall quality of life for patients (Jang, Lee, & Ju, 2021; Olsen, 2024). Given the increasing number of TKA procedures performed annually, the accurate assessment of post-operative recovery and functional outcomes is of paramount importance. In parallel, implant-integrated smart sensor technologies have been proposed to enable objective intraoperative balancing and postoperative monitoring (Iyengar et al., 2021).

Traditionally, the evaluation of post-TKA outcomes has heavily relied on patient-reported outcome measures (PROMs), such as subjective questionnaires about pain and function. While valuable, these methods are inherently limited by their subjectivity, recall bias, and potential for ceiling effects, where patients may report high satisfaction despite persistent functional deficits (Heitkamp et al., 2024; Randall, 2024). In contrast, quantitative, objective methods like laboratory-based three-dimensional gait analysis are considered the gold standard for biomechanical assessment. However, the high cost, complex infrastructure, and time-consuming nature of these systems limit their feasibility and accessibility in routine clinical practice (Gianzina et al., 2023).

In recent years, wearable electronic devices, particularly inertial measurement units (IMUs), have emerged as a promising alternative for the objective and quantitative assessment of gait. These low-cost, portable sensors, typically comprising accelerometers, gyroscopes, and magnetometers, allow for the reliable measurement of spatiotemporal and kinematic parameters of walking in real-world, ambulatory settings (Bolink et al., 2015; Huang et al., 2020). The data captured by these devices can provide clinicians with precise, objective insights into a patient's functional recovery, helping to guide personalized rehabilitation protocols and monitor progress over time. Recent validation work supports the accuracy of wearable IMU systems for estimating knee kinematics during common activities of daily living (Forsyth et al., 2024).

Despite the growing adoption of this technology, there is a need to systematically synthesize the evidence regarding its application in the post-TKA population. A comprehensive understanding of the types of sensors used, the experimental protocols employed, and the specific biomechanical parameters measured is essential to standardize clinical practice and inform future research. Therefore, this systematic review aims to analyze the use of inertial sensors and other electronic devices for the assessment of mobility, function, and gait in patients who have undergone unilateral knee arthroplasty for the treatment of advanced osteoarthritis.

2. METHODOLOGY

This systematic review was registered with PROSPERO under registration number CRD420251002284 and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021).

2.1 Search Strategy and Study Selection

A comprehensive literature search was performed across four major databases: PubMed

(National Library of Medicine), Embase, Scopus and Web of Science. The search strategy utilized a combination of Boolean descriptors and was conducted with no restrictions on publication date, language, or disease severity. The search strategy was carried out from 08/20/2025 to 10/10/2025 using Boolean descriptors and adapted to each database as follows: (Knee Replacement OR Knee Arthroplasty) AND (Gait OR Walk*) AND (Sensor OR Wearable OR Inertial) AND (Spatiotemporal OR Joint angle OR Kinematic* OR Range of motion OR Biomechanic* OR Asymmetr* OR Variability OR Velocity OR Gait speed OR cadence OR step OR "stride length"). The search aimed to identify all relevant studies examining the use of electronic devices and sensors for assessing mobility, function, and gait in patients who had undergone unilateral knee arthroplasty for advanced osteoarthritis.

The selection process involved a two-stage screening performed independently by two reviewers. Initially, titles and abstracts of all identified articles were screened against predefined eligibility criteria. Subsequently, the full texts of the remaining articles were thoroughly assessed for final inclusion. Any discrepancies between reviewers during the screening process were resolved through discussion and consensus. When consensus could not be reached, a third reviewer was consulted. Disagreements were resolved by consensus; when consensus was not reached, a third reviewer adjudicated.

2.2 Eligibility Criteria

Studies were included if they met the following criteria: cross-sectional study design, use of inertial measurement units or other electronic sensors to assess gait parameters, inclusion of patients who had undergone unilateral total knee arthroplasty for osteoarthritis, and reporting of quantitative gait outcomes. We included studies of total knee arthroplasty (TKA) only in which wearable sensors were used to quantify gait/mobility/function outcomes.

For synthesis, studies were grouped a priori into: (1) spatiotemporal outcomes, (2) kinematic outcomes, (3) measurement properties (reliability/validity), and (4) experimental protocols and sensor configurations. Studies were excluded if they did not use inertial sensors or equivalent electronic measurement devices, did not include a post-TKA patient cohort with confirmed arthroplasty status, were not original research articles (e.g., reviews, editorials, case reports), or did not report extractable gait data.

2.3 Data Extraction

Data extraction was performed systematically using a standardized form. Data were extracted independently by two reviewers using a piloted standardized extraction form. Discrepancies were resolved by consensus and, when necessary, by consultation with a third reviewer. When critical information was missing or unclear, we contacted study authors. No automation tools were used for data extraction.

The following information was extracted from each included study: study identification (authors, year, country), sample characteristics (total number of participants, age range, sex distribution, time since surgery), experimental setup (type of walking test, distance, environment), instrumentation (type of sensor, number of units, anatomical placement), gait parameters measured (spatiotemporal, kinematic, kinetic), statistical analysis methods, and main findings. Outcomes of interest were defined a priori and organized into domains: spatiotemporal, gait metrics, kinematic metrics and sensor measurement properties.

We also extracted study design, setting, sample characteristics, time since surgery, comparator groups, sensor type, placement, sampling frequency, walking/task protocol, and analytic approach (including proprietary algorithms when described), as well as funding and conflicts of interest when reported. If arthroplasty type or key protocol details were unclear, we classified as unclear.

2.4 Risk of Bias Assessment

The methodological quality and risk of bias of the included studies were evaluated using an adapted 10-item version of the Downs & Black scale. This tool assesses reporting quality, external validity, and internal validity (bias and confounding). Two independent reviewers performed the quality assessment, and disagreements were resolved through discussion. Studies were not excluded based on quality scores, but the assessment informed the interpretation of findings and the strength of conclusions.

3. RESULTS AND DISCUSSION

3.1 Search Results

The systematic database search initially yielded a total of 219 articles across the three databases. After the removal of duplicates using the Zotero reference management software, 115 unique articles remained for screening. The initial screening of titles and abstracts resulted in the exclusion of 85 articles that clearly did not meet the eligibility criteria. No additional relevant articles were identified through manual searching of reference lists or citation tracking.

The full texts of the remaining 30 articles were retrieved and assessed in detail against the inclusion and exclusion criteria. Following this comprehensive review, 8 articles were excluded for the following reasons: absence of confirmed TKA patient cohort (n=2), use of measurement systems other than inertial sensors (n=3), duplicate publication of the same dataset (n=1), and insufficient reporting of gait parameters (n=2). This rigorous selection process resulted in a final cohort of 21 cross-sectional studies being included in the systematic review (Fig. 1).

3.2 Study and Population Characteristics

The 21 included studies, Table 1, comprised a total of 758 patients who had undergone total knee arthroplasty (TKA) for advanced osteoarthritis and approximately 210 healthy controls who served as comparison groups in several studies.

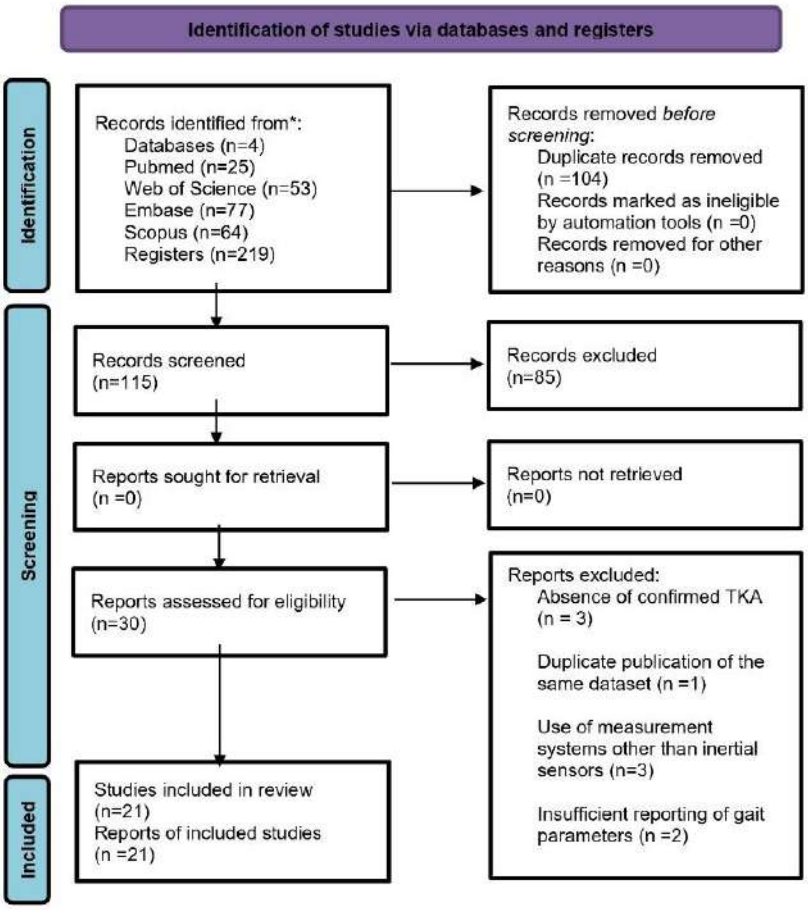

Fig. 1. Prisma flowchart for study selection

Table 1. Characteristics of the included studies

Study	Sample	Experimental protocol	Sensor configuration	Main findings
Tereso et al. (2015)	N= 11 patients with TKA	Walking of approximately 10 meters in a corridor, 3 trials per condition (crutches, standard walker, and rollator with forearm support), on days 5 and 15 post-TKA.	SMI MP6000 and InvenSense Accelerometers.	All spatiotemporal parameters varied significantly between 5 and 15 days ($p<0.05$); Walkers (Ads) affected TStride, TStance, velocity, and cadence ($p<0.05$), with no effect on TSwing and SL.
Sato et al. (2024)	N=8 patients with TKA (11 knees) F: 4 M: 4	Gait analysis during a 10 m walk, performed three times before surgery and three times ≥ 6 months after TKA.	IMU-Z2 (triaxial accelerometer + gyroscope + magnetometer) from ZMP Inc.	Lateral thrust: prevalence of 81.8% pre-UKA → 55.6% post-UKA Varus angular velocity: 37.1 ± 9.8°/s (pre) → 28.8 ± 9.1°/s (p = 0.00003) Oxford Knee Score: 28.3 → 40.1 (p = 0.003)
Emmerzaal et al. (2022)	N= 39 Control: 20 asymptomatic individuals Comparison: 19 patients with osteoarthritis treated with TKA	Gait analysis during three activities of daily living: level walking and stair ascent/descent.	17 IMU units (triaxial accelerometer, gyroscope, and magnetometer) MVN BIOMECH Awinda (Xsens Technologies), sampling at 60 Hz.	Classification accuracies between 91.67% and 100% for models trained on preoperative data and at 6 weeks post-TKA. Preoperative: Stair models reduced the probability o TKA in only 27% of participants; the walking model classified all as asymptomatic as early as 6 weeks post-op.
Huang et al. (2020)	N=8 patients with TKA F: 2 M: 6	Knee flexion/extension exercise (leg swings) in a seated position to simulate home rehabilitation and	IMU module based on the MPU6050 (triaxial accelerometer + gyroscope) integrated	Mean absolute error of ROM (TKR): 1.65° (25°/s), 2.74° (60°/s), 3.27° (180°/s)

Study	Sample	Experimental protocol	Sensor configuration	Main findings
		speed 50 m run at maximum possible speed.		steps/min Step length: ↑ on average +0.10 m Running speed: average increase of +0.48 m/s (individual vari...
Rahman et al. (2015)	N= 103 74 patients with TKA (M: 32, F: 42) 29 healthy controls (M: 12, F: 17)	10-meter corridor walk (10 m out, 180° turn, and 10 m back), performed in an outpatient clinic.	Inertial measurement units (IMUs GaitSmart, ETB, UK) containing three tri-axial accelerometers and three tri-axial gyroscopes.	Over the 12 months postoperatively, there was an increase of approximately 10° in knee flexion range of motion during swing in the operated limb; Knee_stance was the variable with the greatest weight.
De Vroey et al. (2018)	N= 16 post-TKA patients F: 8 M: 8	Three barefoot walking trials at a self-selected speed along a flat 6 m pathway.	Xsens MTw units (IMUs with accelerometer and gyroscope), sampling at 100 Hz.	Cycle Time: Operated: ICC 0.979; bias – 0.018 s; RMSE 0.036 s Non-operated: ICC 0.972; bias 0.006 s; RMSE 0.041 s Stance Time: Operated: ICC 0.953; bias 0.026 s; RMSE 0.041 s Non-operated: ICC 0.913; bias 0.041 s; RMSE 0.054 s.
Roberts et al. (2013)	N= 45 27 patients with TKA (M:11, F:16) 18 control patients (M:7,	Five ADL activities (Level walk – 3 steps and stop; 90° Pivot; Sit-to-Stand; Step-up/Step-down on a 7-inch platform; Reverse Pivot).	IMU "Motion Node" (triaxial accelerometer + triaxial gyroscope + magnetometer), sampling rate 100 Hz.	Instability: 24 out of 38 TKA knees reported instability; Activity 4 was the most critical. Significant parameters: 22 variables showed $p<0.05$ (17 on

Study	Sample	Experimental protocol	Sensor configuration	Main findings
				% Cadence: 3.2–4.1 % Speed: 6.4–9.6 % Step length: 7.6–9.7 % Stride length: 7.1–9.6 % Step width: 34.9–40.9 % Toe-out angle: 73.7–80.6 %
Bolam et al. (2021)	N=14 participants with TKA F: 6 M: 8	Weekly remote monitoring sessions in a community setting, using ankle-mounted IMUs to record approximately 8–10 hours of daily activities between Weeks 2 and 6 post-op.	Vicon Blue Trident IMU (tri-axial accelerometer and gyroscope; 1,149 Hz).	Bone Stimulus: ↑52% (90.73 ± 28.19 → 138.21 ± 19.70; p = 0.002) Cumulative Impact Load: ↑371% (1,424.77 ± 1,637.87 → 5,290.01 ± 2,606.97; p = 0.035) Load Asymmetry: −17.55 ± 16.50 → −10.62 ± 15.88 (p= 0.308) Oxford Knee Score: 25.60 ± 8.83 → 36.46 ± 6.91 (Δ +10.86; p < 0.001) EQ-5D Index: 0.63 ± 0.191 → 0.83 ± 0.152 (Δ +0.20; p = 0.047) 6-Minute Walk Test: 372.14 ± 61.57 m → 417 ± 136.32 m (p = 0.688) Max Knee Flexion: 91.45 ± 1.40° → 99.25 ± 9.59° (p = 0.156)
Chapman et al. (2021)	N= 10 participants with TKA	Continuous use of IMUs for capturing knee RoM, divided	Emerald IMUs (APDM Inc.; tri-axial	Maximum flexion RoM: non-PT > PT (F = 9.77; p = 0.003)

Study	Sample	Experimental protocol	Sensor configuration	Main findings
	F: 3 M: 7	into "PT" periods (during physiotherapy sessions) and "non-PT" periods (all other hours of the day) over 1-week pre-TKA and 6 weeks post-TKA.	accelerometer, 128 Hz, ± 6 g).	RoM in stance: PT > non-PT (F = 22.62; p < 0.0001) RoM in swing: PT > non-PT (F = 52.80; p < 0.0001) Stride time: no effect of location (F = 1.46; p = 0.23) Stance time: no effect of location (F = 0.22; p = 0.64)
Lou et al. (2022)	N = 20 participants 10 TKR (F:7 / M:3) 10 Healthy (F:7 / M:3)	Type of test: three modalities of knee flexion–extension: 1. Passive: guided by the BTE Primus RS at 15°, 30°, and 45°/s (2 repetitions each) 2. Active: self-controlled in seated position.	Two portable IMUs (MPU9250: tri-axial accelerometer, tri-axial gyroscope, electronic compass; MCU STM32F407; Bluetooth HC-06), 100 Hz.	Mean absolute error ROM TKR: 3.22° ± 4.23° (15°/s); 4.94° ± 4.72° (30°/s); 4.34° ± 5.02° (45°/s). Mean absolute error ROM healthy: 0.76° ± 4.10° (15°/s); 0.63° ± 3.62° (30°/s); 0.16° ± 4.37° (45°/s).
Boekesteijn et al. (2022)	N= 75 TKA: 24 (M:12, F:12) THA: 24 (M:16, F:8) Healthy controls (HC): 27 (M:13, F:14)	2-minute walk test, back and forth on a 6 m track with 180° turns.	Four Opal V2 units (APDM Inc.) — IMUs with integrated accelerometer and gyroscope.	Walking speed Baseline: 0.99 m/s (TKA) and 0.96 m/s (THA) 2 months: −0.04 m/s (TKA), +0.04 m/s (THA) 15 months: +0.22 m/s (TKA), +0.14 m/s (THA).
Yeung et al. (2022)	N= 10 participants undergoing TKA	Continuous "off-site" monitoring of tibial acceleration peak ("tibial shock") during daily	IMU IMeasureU Blue Thunder (tri-axial accelerometer, 1 kHz,	Healthy cohort: R^2 = 0.70–0.97 between tibial shock and knee reaction force

Study	Sample	Experimental protocol	Sensor configuration	Main findings
	F: 7 M: 3	activities, using sensors worn for approximately 8 hours in a home/community environment.	Bluetooth LE, battery ~8 h).	Tibial shock profiles in 10 patients: Stable (n=3): tibial shock remained at ~0.6–2.5 Gs Improving (n=5): increase of 30%.
van de Vem et al. (2023)	N= 22 participants TKA: 11 (M:5, F:6) Control: 11 (M:5, F:6)	Treadmill walking at individual comfortable walking speed (CWS), with 3 minutes of warm-up followed by continuous measurements on an Excite treadmill (Technogym, Cesena, Italy).	4 MTw inertial sensors (XSens Technologies B.V., Enschede, NL), each with a triaxial accelerometer, gyroscope, and magnetometer; sampling at 100 Hz.	Effect of time (TKA): Cadence: ↑ from 51.0 to 54.6 steps/min (linear trend $p = 0.024$) SEn: ↑ from 0.22 to 0.26 (linear $p < 0.001$). Amplitude and peak frequency did not change significantly over time.
van de Ven et al. (2024)	N=22 participants TKA: 11, with 9 completing the collections (M:4, F:5) Control: 11	Treadmill walking under three speed conditions (70%, 100%, and 130% of comfortable speed), with 5 trials of 40 seconds per condition, following a 3-minute warm-up.	1 MTw IMU (XSens; tri-axial accelerometer and gyroscope), 100 Hz.	Pre-TKA vs. controls: greater amplitude ($p=0.025$); lower SEn ($p=0.038$). Recovery: amplitude decreased linearly until leveling with controls at 12 months ($p=0.007$; $\eta p^2=0.392$).
Piovan et al. (2024)	N= 154 MB-UKA (Metal Prosthetic Tibial Component): 32 men and 45 women AP-UKA (Polyethylene Prosthetic Tibial Component): 30 men and 47 women	Assessment of postural stability ("static postural sway"), mobility, and gait symmetry at 5 years, using the Riablo™ system in five functional tasks (Timed Up & Go).	Riablo™ System (20 g Bluetooth™ IMUs, 50 Hz) + inertial pressure platform.	Static postural sway: 3.9 ± 2.1 cm (MB) vs. 5.4 ± 2.3 cm (AP), $p = 0.0002$ Mobility: 70.9 ± 18.6% (MB) vs. 74.4 ± 18.6% (AP), $p = 0.062$ Gait symmetry: 92.7 ± 3.7% (MB) vs. 90.4 ± 5.4% (AP), $p = 0.006$

3.3 Experimental Protocols and Sensor Configuration

The use of inertial sensors varied considerably across the included studies. The number of sensor units employed ranged from a single unit to as many as 15 units for full-body kinematic analysis. The most common configuration involved a single sensor placed on the lumbar spine or sacral region, which was used in approximately one-third of the studies. Multi-sensor setups typically included placement on the pelvis, thighs, shanks, and feet to capture lower limb kinematics comprehensively.

Walking protocols demonstrated substantial heterogeneity. The most frequently employed protocol was short-distance overground walking, with distances ranging from 6 to 40 meters at self-selected speeds. Several studies utilized treadmill-based assessments at controlled speeds. A smaller number of studies implemented oval or figure-eight walking circuits to assess turning and dynamic balance. Notably, a subset of recent studies employed continuous "free-living" monitoring over extended periods (hours to days) to capture real-world gait patterns in patients' home environments.

3.4 Gait Parameters and Measurement Reliability

The primary parameters collected across the studies were spatiotemporal and kinematic variables. Spatiotemporal variables consistently included gait speed (m/s), cadence (steps/min), step length (m), stride time (s), and the duration of different gait phases (stance, swing, double support). These parameters provide fundamental information about the temporal and spatial characteristics of walking patterns.

Kinematic variables focused predominantly on knee joint angles throughout the gait cycle, including peak flexion during swing phase, extension at heel strike, and range of motion. Several studies also quantified compensatory movements of the pelvis and trunk, including pelvic tilt, obliquity, rotation, and trunk sway in multiple planes. These compensatory patterns are particularly relevant as they may indicate persistent functional limitations or adaptive strategies following TKA.

The included studies consistently demonstrated strong measurement properties for inertial sensors. Reliability, assessed through intraclass correlation coefficients (ICC), exceeded 0.85 for most spatiotemporal parameters. Validity, evaluated by comparison with gold-standard optical motion capture systems, showed angular errors of less than 5 degrees for knee joint angles. These findings support the use of inertial sensors as accurate and reliable tools for gait assessment in post-TKA populations.

3.5 Risk of Bias Assessment

The quality assessment using the adapted Downs & Black scale revealed that many included studies demonstrated moderate to high methodological quality. Most studies provided clear descriptions of their objectives, main outcomes, patient characteristics, and interventions. However, several studies showed limitations in reporting of potential confounders and in the representativeness of their samples. External validity was often limited by small sample sizes and single-center recruitment. These limitations should be considered when interpreting the overall findings of this review.

3.6 Key Findings and Gaps in the Literature

The collective evidence from the 22 included studies reveals that patients following TKA consistently exhibit persistent spatiotemporal deficits compared to healthy age-matched controls. These deficits include reduced gait speed, decreased cadence, shorter step length, and prolonged double support time. Kinematic alterations, particularly reduced knee flexion range of motion and compensatory trunk and pelvic movements, were also consistently observed.

A notable gap identified in the current literature is the absence of studies that explicitly investigated or stratified results based on the type or design of the knee prosthesis. None of the included studies compared outcomes between different implant designs (e.g., cruciate-retaining vs. cruciate-substituting, fixed vs. mobile bearing). This represents a significant limitation in understanding whether prosthesis design influences gait biomechanics as measured by inertial sensors.

4. CONCLUSION

Across 21 cross-sectional studies encompassing 758 patients and 210 healthy controls, inertial-sensor assessments consistently detected persistent spatiotemporal deficits and kinematic alterations after total knee arthroplasty, with good measurement properties (typically ICC >0.85 and angular error <5°). Protocols ranged from short walkway and treadmill tasks to free-living monitoring using 1–15 sensors—most commonly on the lower back/pelvis—underscoring the versatility of these tools for functional evaluation. Clinically, wearable inertial sensors provide objective, scalable, and low-cost monitoring that complements conventional outcome measures and can support individualized rehabilitation planning and remote follow-up when implemented with validated workflows.

However, methodological heterogeneity—spanning device types, placement, protocols, and opaque, "black-box" algorithms—limited between-study comparability and precluded formal meta-analysis, and few studies stratified outcomes by implant design. These gaps hinder the establishment of normative thresholds and slow clinical adoption. Future research should prioritize standardized protocols, transparent analytic pipelines (with open methods/code), and adequately powered longitudinal cohorts from pre- to long-term post-operative phases, including cost-effectiveness analyses and stratification by prosthesis type.

This synthesis supports inertial sensors as valid and practical instruments for post-arthroplasty functional assessment while highlighting the field's imperative to harmonize methods to accelerate translation into routine orthopedic care. In keeping with SDI guidance, these statements briefly state the major findings and implications of the review.

CONSENT

It is not applicable.

ETHICAL APPROVAL

The review protocol was prospectively registered in the international prospective register of systematic reviews (PROSPERO) under id CRD420251002284, developed a priori and conducted in accordance with PRISMA Checklist 2020 (Annex 1).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors declare the utilization of GPT-4 to assist in the linguistic refinement of this manuscript. The tool was employed exclusively to enhance the grammatical accuracy and readability of the text, which was originally drafted in Brazilian Portuguese and subsequently translated into English. The AI's contribution was strictly limited to stylistic and linguistic improvements, without generating new content or altering the scientific substance. Specifically:

1. Following the initial translation from Brazilian Portuguese, the AI was tasked with polishing the English text to ensure consistency with conventional academic usage.

2. Targeted prompts were issued to rectify grammatical inaccuracies and uphold the formal tone required for scientific publication.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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8.6.2 Instrumented Functional Mobility Assessment in Elderly Patients Following Total Knee Arthroplasty: A Retrospective Longitudinal Study Using the Timed Up and Go Test

Trindade AMVD, Rezende LP, Araújo HRDS, Parreira RB, Oliveira CS. Instrumented Functional Mobility Assessment in Elderly Patients Following Total Knee Arthroplasty: A Retrospective Longitudinal Study Using the Timed Up and Go Test. Life (Basel). 2025 Sep 7;15(9):1409. doi: 10.3390/life15091409. PMID: 41010351

Life – Qualis Capes A2

Em estudo longitudinal retrospectivo foi avaliado a mobilidade funcional de idosos submetidos à artroplastia total unilateral de joelho, via acesso transquadricipital, utilizando o Timed Up and Go (TUG) instrumentado com unidade inercial (G-Sensor®) posicionada em L5. Dezenove pacientes (50–80 anos, OA grau ≥4 de Kellgren Lawrence) foram avaliados em dois momentos pós-operatórios tardios (aproximadamente 18 e 53 meses), com extração de 15 variáveis cinemáticas segmentadas (transições sentar levantar, marcha e fases de giro). O tempo total de TUG manteve-se estável entre as avaliações (14,97 ± 3,48 vs. 15,47 ± 2,93 s; p = 0,58), indicando desempenho global estacionário. Contudo, observou-se aumento significativo e com grande magnitude de efeito na velocidade de pico do giro intermediário (mid-turning: 106,44 ± 30,96 vs. 132,77 ± 30,82°/s; p = 0,0039; r = 0,88), além de incrementos moderados na velocidade de giro final (end-turning) e discreta melhora em parâmetros de transferência (sit-to stand), embora sem significância estatística. Esses achados sugerem que, mesmo após o primeiro ano de pós-operatório, há refinamento tardio da fluidez do movimento e do controle motor em tarefas complexas de mudança de direção, reforçando a relevância do TUG instrumentado para detectar déficits sutis não captados apenas pelo tempo total de teste e indicando a necessidade de programas de reabilitação prolongados, com ênfase em controle rotacional e equilíbrio.

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Instrumented Functional Mobility Assessment in Elderly Patients Following Total Knee Arthroplasty: A Retrospective Longitudinal Study Using the Timed Up and Go Test

Andrei Machado Viegas da Trindade [1,2], Leonardo Pinheiro Rezende [3,*], Helder Rocha da Silva Araújo [4], Rodolfo Borges Parreira [5] and Claudia Santos Oliveira [2,5]

1 Department of Orthopedics Surgery, Municipal Hospital of Aparecida de Goiânia (HMAP), Aparecida de Goiânia 74936-600, Brazil; andrei.trindade@einstein.br
2 Health Sciences Program, Santa Casa de São Paulo School of Medical Sciences, São Paulo 01221-020, Brazil; csantos.neuro@gmail.com
3 Faculty of Medicine, University Evangelica of Goiás, Anápolis 75083-515, Brazil
4 Department of Orthopaedics and Traumatology, Federal University of Goiás (UFG), Goiânia 74605-050, Brazil; drhelderrocha@hotmail.com
5 Human Movement Analysis Laboratory, University Evangelica of Goiás, Anápolis 75083-515, Brazil; rodolfo.fcmscsp@gmail.com
* Correspondence: leonardorezende4@gmail.com

Abstract

In the context of the rising demand for total knee arthroplasty (TKA) in older adults and persistent uncertainty about the quality of long-term functional recovery, this study evaluated elderly patients' mobility after unilateral TKA via a transquadriceps approach using instrumented Timed Up and Go (TUG) tests. A total of 20 patients treated between 2022 and 2024 at a tertiary hospital were invited to participate in this observational, retrospective, descriptive study, and 19 met the inclusion criteria (age 50–80 and Kellgren–Lawrence $\geq$ 4). The participants performed two TUG trials at two postoperative time points (18 and 53 months), with an inertial measurement unit (G-sensor) capturing 15 kinematic variables. When comparing the postoperative time points, it was found that the total TUG duration remained stable (14.97 $\pm$ 3.48 vs. 15.47 $\pm$ 2.93 s; p = 0.58), while the mid-turning peak velocity increased significantly (106.44 $\pm$ 30.96 vs. 132.77 $\pm$ 30.82°/s; p = 0.0039; r = 0.88). The end-turning velocity and sit-to-stand parameters showed small-to-moderate effect size gains without statistical significance. These findings suggest that, in the first year following surgery, patients continue to experience difficulties with movement fluidity and motor control—especially during turning—underscoring the value of segmented, sensor-based assessments and the need for extended rehabilitation protocols that emphasize rotational control and balance. These findings provide clinically relevant parameters that can support future interventional studies and help guide rehabilitation planning after TKA.

Keywords: arthroplasty; replacement; knee; gait; accelerometry; timed up and go test; rehabilitation

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1. Introduction

Osteoarthritis (OA) is a degenerative joint disease that predominantly affects older adults and is the leading indication for total knee arthroplasty (TKA) [1]. Its prevalence increases with age, and most patients undergo TKA between 60 and 80 years of age [2].

Advanced degenerative or inflammatory disease is commonly treated by TKA, an orthopedic procedure that is both highly prevalent and effective for end-stage OA, providing pain relief and improving quality of life, particularly in older adults. Nevertheless, long-term functional recovery often fails to reach the levels observed in age-matched healthy individuals. When performed via the transquadricipital (medial parapatellar) approach, TKA requires a longitudinal incision through the quadriceps tendon to expose the joint [3]. The principal advantage of this traditional quadriceps-splitting medial parapatellar technique is its familiarity to surgeons and the excellent exposure it affords, facilitating intraoperative visualization and manipulation.

TKA is among the most successful and commonly performed orthopedic procedures worldwide, principally in individuals over 60 years of age to treat advanced OA [4]. Demand for TKA is projected to increase substantially as populations age and the prevalence of degenerative joint disease rises [5]. A similar upward trend has been observed in Brazil, where the number of TKAs performed by the Unified Health System (SUS) within this age group has grown [6].

Despite well-established benefits of TKA, gaps remain in the comprehensive understanding of functional recovery in older adults, particularly with respect to movement quality and asymmetries between the operated and non-operated limbs [7]. Recent studies using wearable sensors such as IMUs indicate that, even after conventional rehabilitation, subtle deficits persist in gait biomechanics, dynamic postural control during functional tasks, and the ability to perform rapid, safe changes of direction [5,8]. Therefore, detailed characterization of these residual impairments and their associations with different surgical techniques and rehabilitation approaches remains necessary to optimize long-term outcomes [9].

Violation of the extensor mechanism inherent to the transquadricipital approach frequently leads to postoperative quadriceps weakness, which impairs functional mobility and manifests as difficulty with ambulation and rising from a chair [10]. Accurate evaluation of these functional deficits, therefore, requires methods that capture movement quality in addition to simple timing measures. Instrumenting the Timed Up and Go (TUG) test with an inertial measurement unit (IMU) enables quantitative, segmented analysis of performance, providing parameters such as acceleration profiles and angular smoothness during sit-to-stand transitions and turning maneuvers [11,12]. This objective, sensor-based diagnostic approach is essential for detecting subtle limitations and for guiding more targeted rehabilitation strategies in older adults following arthroplasty [13].

Given this persistent gap in knowledge about the quality of motor recovery, the present study asks: what is the functional performance of elderly patients following unilateral TKA via the transquadricipital approach when evaluated quantitatively with an IMU during the TUG test? The study's relevance derives from employing objective, high-resolution metrics to characterize deficits not captured by conventional timed assessments. Although the transquadricipital approach is widely used, few investigations have applied IMU-based analyses to objectively evaluate long-term post-surgical outcomes and to inform more specific rehabilitation protocols. In particular, sensor-based analyses of complex movements such as turning in elderly TKA patients remain scarce. Accordingly, we assessed functional mobility patterns in older adults after TKA using instrumented TUG testing at two postoperative time points. We hypothesized that certain kinematic parameters—especially those related to turning and transitional movements—would improve over time, whereas overall task duration might remain stable.

2. Materials and Methods

This is an observational, retrospective, and descriptive study conducted with patients who underwent unilateral total knee arthroplasty (TKA) via the transquadricipital surgical approach, aimed at identifying and describing those who were operated on using this technique.

Initially, the target population comprised 19 patients who underwent total knee arthroplasty (TKA) at a tertiary hospital in Goiás, Brazil, between 2022 and 2024. All patients underwent primary TKA under spinal anesthesia via a transquadricipital approach at the same hospital and by the same surgical team; all received implants from a single manufacturer, were managed by the same inpatient physical therapy team, and adhered to a standardized postoperative rehabilitation protocol. The sample size calculation was based on the findings of Pfeufer et al. (2022) [14], who observed a mean increase of 0.27 m/s in gait speed (from 0.75 to 1.02 m/s) between 2 and 6 weeks after primary TKA, measured using an instrument. Considering a significance level of 0.05, a power (1–β) of 0.80, and a paired *t*-test, as well as adopting a conservative standard deviation of 0.30 m/s for the paired difference, we estimated a minimum required sample size of 14 participants to detect this effect; to accommodate potential loss to follow-up (~25%), the sample was increased to 18 patients.

The inclusion criteria required individuals to present with advanced knee osteoarthritis (grade ≥ 4 according to the Kellgren and Lawrence scale), be aged 50–80 years, and have undergone their first surgery for osteoarthritis via the transquadriceps approach. The exclusion criteria comprised neurodegenerative diseases, secondary osteoarthritis, primary unilateral total arthroplasty via a subvastus approach, prior knee surgeries, a history of knee fracture within the previous 12 months, hip arthroplasty, pre- or postoperative infections, comorbidities that could compromise recovery and rehabilitation, or a history of revision knee arthroplasty.

Two postoperative follow-up intervals were chosen a priori to capture both mid-term stabilization and the long-term sustainability of functional recovery. The first assessment (18 months) corresponded to the period when most patients complete standard rehabilitation, and functional gains typically plateau [15,16]. The second assessment (53 months) was scheduled at approximately 4 years post-surgery to evaluate whether improvements in gait quality and inter-limb symmetry were maintained, declined, or further adapted over time—an interval for which there are minimal instrumented data in the literature [17,18]. These time points also aligned with routine clinical follow-up visits, ensuring the feasibility of recruitment and the consistency of testing conditions.

Assessments were conducted over a maximum of 30 min per day. The participants were evaluated using an IMU (G-Sensor®, BTS Bioengineering®, Garbagnate Milanese, Italy) during the execution of the Timed Up and Go (TUG) test. This sensor captured and stored 15 variables related to functional mobility parameters. For each patient, the mean of three TUG repetitions was used. Evaluations took place at two time points: in the initial postoperative assessment (mean: 12 months after surgery) and in a second evaluation approximately 2 years after the surgical intervention. At the outset, the participants completed an identification form, and anthropometric data (body weight, height, and body mass index) were recorded.

The TUG test quantifies, in seconds, the time required for an individual to rise from a standard chair (without armrests), walk three meters, perform a turn, return to the starting point, and sit down again [16]. The participants were instructed to perform the test at a self-selected, safe speed to minimize the risk of falling. Two trials were conducted, with the first serving as a familiarization trial.

Data were collected via a portable G-Sensor® (BTS Bioengineering®, Garbagnate Milanese, Italy) positioned at the L5 vertebral level. This wireless inertial system, designed for human motion analyses, is controlled by a data recording unit (capable of supporting up to 16 sensors) via ZigBee radio communication. Each sensor measures 62 × 36 × 16 mm; weighs 60 g; and comprises a triaxial accelerometer (±6 g), a triaxial gyroscope (±300°/s), and a triaxial magnetometer (±6 Gauss). The device is calibrated against gravitational acceleration immediately after manufacture. For this study, a single sensor was used, configured at a sampling frequency of 50 Hz. The captured data were transmitted via Bluetooth to a computer and processed with proprietary software (BTS G-STUDIO®, version 2.6.12.0), which automatically provided the parameters of interest [19].

Statistical analyses were performed by one of the authors using procedures appropriate for the nature of the data and the study's longitudinal design. First, the normality of quantitative variables was assessed with the Shapiro–Wilk test, which is recommended for small samples. This procedure determined whether parametric or nonparametric tests would be used for subsequent comparisons.

Descriptive statistics are presented as measures of central tendency (mean and median) and dispersion (standard deviation, minimum, and maximum values). To compare the results between the two evaluation time points—denoted as Collection 1 and Collection 2—the following tests were applied: a paired *t*-test for variables exhibiting a normal distribution to compare means and the Wilcoxon signed-rank test for variables that violated normality assumptions to compare medians or the direction of paired differences.

In addition to statistical significance testing, effect sizes were calculated to quantify the magnitude of the observed differences independently of the *p*-values. Cohen's d was used for parametric tests, and the nonparametric effect size coefficient r was computed as $r = z/\sqrt{n}$. Effect magnitudes were classified conventionally as slight, moderate, or significant.

Correlation analyses were also conducted to explore the associations between biomechanical variables, such as time, acceleration, and velocity, during different test phases. Pearson's correlation coefficient was applied to normally distributed data, and Spearman's rank correlation was applied to nonparametric data. In all analyses, a 5% significance level ($p < 0.05$) was used.

Data were initially organized in Microsoft Excel spreadsheets, and subsequent statistical analyses were conducted using IBM SPSS Statistics®, version 2019. Artificial intelligence (AI) was not used for literature searches or scientific writing.

3. Results

An initial cohort of 20 patients was invited to participate in this longitudinal study. Of these, 19 attended an outpatient clinic for a functional evaluation to determine whether they met the inclusion criteria, and their epidemiological characteristics are detailed in Table 1.

A descriptive analysis of the functional and biomechanical variables revealed the sample's central parameters at two distinct time points: Collection 1 (18-month postoperative follow-up) and Collection 2 (53-month postoperative follow-up). The evaluated variables included execution time, accelerations during the sit-to-stand and stand-to-sit phases, and velocities and durations of the turning phases (mid-turning and end-turning).

Regarding the total task duration, a mean of 14.97 ± 3.48 s was observed in Collection 1 (median 14.72 s), with a slight increase to 15.47 ± 2.93 s in Collection 2 (median 14.76 s). These findings suggest that overall functional mobility performance was stable over time, with no marked changes in the total execution time.

Table 1. Demographic and clinical characteristics of the patient sample (n = 19).

Variable	Mean ± SD	Minimum	Maximum
Age (years)	69.2 ± 6.1	60	82
Height (m)	1.61 ± 0.11	1.40	1.87
Weight (kg)	100.9 ± 20.1	69.3	138.1
BMI (kg/m^2)	31.3 ± 4.2	24.8	41.2
Postoperative time—Collection 1 (months)	17.3 ± 2.1	15.2	19.4
Postoperative time—Collection 2 (months)	42.8 ± 3.5	39.3	46.3
Categorical Variable	***n* (%)**		
Right limb	14 (73.7%)		
Left limb	5 (26.3%)		

Legend: SD: standard deviation; BMI: body mass index; *n*: absolute frequency.

For variables associated with the sit-to-stand transition, the mean time was 1.95 ± 0.46 s in Collection 1, decreasing slightly to 1.76 ± 0.40 s in Collection 2, indicating a possible improvement in task agility. Anteroposterior, mediolateral, and vertical accelerations showed minimal variation between collections, thus maintaining similar profiles—for example, anteroposterior acceleration averaged 3.92 ± 1.81 m/s^2 in Collection 1, compared to 3.78 ± 2.40 m/s^2 in Collection 2. For the stand-to-sit movement, the mean time was 2.08 ± 0.42 s in Collection 1, rising slightly to 2.30 ± 1.10 s in Collection 2 with increased dispersion, which may reflect greater interindividual variability in the sitting strategy in the later evaluation.

The mid-turning phase demonstrated clinically relevant improvements in velocity. The peak mid-turning velocity increased from 106.44 ± 30.96°/s in Collection 1 to 132.77 ± 30.82°/s in Collection 2, while the mean velocity rose from 65.22 ± 21.54°/s to 68.39 ± 22.07°/s, indicating significant functional gains in turning ability, as supported by the statistical results previously reported.

Velocities also increased in the end-turning phase. The peak end-turning velocity rose from 135.40 ± 25.07°/s in Collection 1 to 141.85 ± 22.22°/s in Collection 2, and the mean velocity increased from 67.01 ± 13.81°/s to 76.77 ± 11.93°/s, reflecting enhanced fluidity and motor control at task completion (Figure 1).

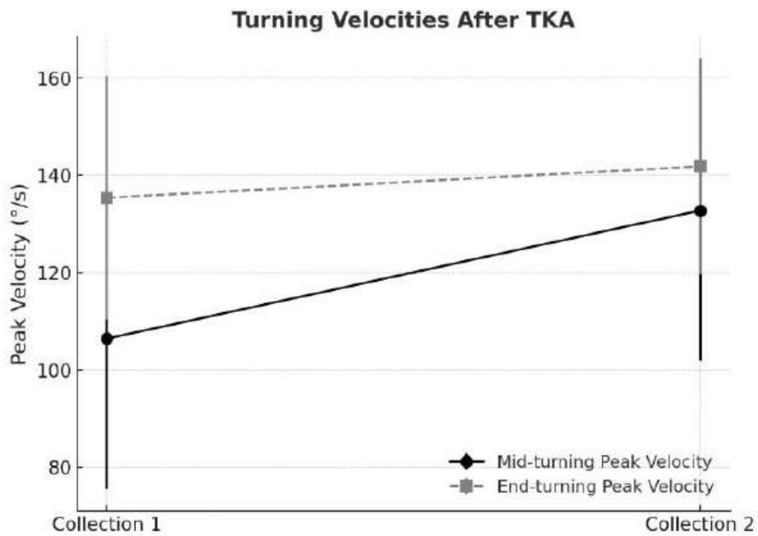

Figure 1. Mid-turning and end-turning velocity changes.

Regarding the duration of turning phases (mid-turning and end-turning), the values remained stable between collections, with small average reductions that appeared not to be clinically meaningful but may reflect subtle adjustments in locomotor strategy.

In summary, the descriptive results indicate the maintenance of global task performance over time, coupled with specific gains in turning velocities (mid-turning and end-turning) and modest improvements in transfer tasks (sit-to-stand). This suggests that, even beyond the first postoperative year, patients tend to refine aspects of movement fluidity and dynamic postural control.

3.1. Sample Normality

The normality of the data was assessed using the Shapiro–Wilk test, which is considered appropriate for small-to-moderate sample sizes [1]. Quantitative variables from both collections were evaluated, including execution time, accelerations during the sit-to-stand and stand-to-sit phases, and velocities in the mid-turning and end-turning phases. A significance level of 5% ($p < 0.05$) was adopted. According to the Shapiro–Wilk test, the total task duration in Collection 1 ($p = 0.4511$) and vertical acceleration during the sit-to-stand task in Collection 1 ($p = 0.3222$) exhibited normal distributions ($p > 0.05$).

However, the majority of variables did not follow a normal distribution, as was the case for other acceleration and velocity measures in the mid-turning and end-turning phases. A visual inspection of histograms and Q–Q plots corroborated the statistical test results, revealing right-skewed patterns, particularly for the acceleration variables, which were clustered at lower values, with outliers at higher values [2]. Overall, these findings indicate a mixture of normally and non-normally distributed variables in the sample, justifying the use of nonparametric tests for most of the comparative analyses.

3.2. Statistical Test to Assess Significance Between Variables

A comparison between Collection 1 (18 months postoperatively) and Collection 2 (53 months postoperatively) was conducted based on the assessment of data normality, which guided the selection of the statistical tests. Table 2 presents the results of the Shapiro–Wilk normality test for each variable in both collections, as well as the results of the paired comparison tests.

Table 2. Comparison of statistical tests between Collection 1 (18 months postop) and Collection 2 (53 months postop).

Variable	Test	Shapiro–Wilk p Collection 1	Shapiro–Wilk p Collection 2	Test Statistic	p Value
Total Task Duration	Paired t-test	0.4511	0.1128	−0.5598	0.5825
Sit-to-Stand Duration	Wilcoxon signed-rank test	0.0391	0.7071	52.5	0.1505
Sit-to-Stand Anteroposterior Acceleration	Wilcoxon signed-rank test	0.0409	0.0001	85.0	0.9826
Mid-Turning Peak Velocity	Wilcoxon signed-rank test	0.0022	0.2905	26.0	0.0039
End-Turning Peak Velocity	Paired t-test	0.6651	–	−1.2425	0.2300

It was observed that only the variable related to the peak velocity during mid-turning (intermediate turn) showed a statistically significant difference between the collections ($p = 0.0039$). This finding indicates a significant improvement in the patients' performance when executing turns, suggesting gains in agility, stability, and motor control—key factors for functionality in daily living activities.

By contrast, the total task duration ($p = 0.5825$), sit-to-stand duration ($p = 0.1505$), sit-to-stand anteroposterior acceleration ($p = 0.9826$), and peak velocity during end-turning ($p = 0.230$) did not exhibit statistically significant differences between evaluations. Nevertheless, the mean values and trend plots indicate a tendency toward clinical improvement—

particularly in postural transition tasks and final turns—even though this did not reach statistical significance.

These findings support the hypothesis that, over a multi-year postoperative period, patients achieve greater improvements in turning-phase gait metrics (mid-turning and end-turning velocities) than in transition-phase metrics (sit-to-stand and stand-to-sit durations).

3.3. Spearman's Correlation Analysis

Spearman's correlation was chosen due to the nonparametric nature of most variables, as indicated by the Shapiro–Wilk tests. This monotonic correlation coefficient (ρ) is less affected by non-normality and outliers, allowing for an assessment of consistent relationships among the temporal, acceleration, and velocity domains without assuming strict linearity. In the relationship between global performance (total duration) and postural transfers, a moderate positive correlation was observed in Collection 2 (53 months) between the total duration and sit-to-stand duration ($\rho = 0.54$), suggesting that slower individuals also generally took longer to complete the sit-to-stand phase in this later stage of recovery.

Conversely, in Collection 1 (18 months), anteroposterior acceleration during the sit-to-stand maneuver showed a moderate negative correlation with the total duration ($\rho = -0.58$), indicating that patients who could generate greater initial leg force completed the entire test more quickly. An analysis of the relationship between transfer acceleration and turning velocity revealed a moderate positive correlation in Collection 1 between anteroposterior acceleration in the sit-to-stand maneuver and the peak mid-turning velocity ($\rho = 0.35$), suggesting that the ability to develop momentum when rising may improve dynamic control and speed during intermediate direction changes.

Furthermore, in Collection 2 (53 months), the peak velocities during mid-turning and end-turning showed a strong correlation ($\rho = 0.60$), suggesting that patients with improved agility in one turning phase tended to maintain high performance in the next phase. Lastly, the cross-collection correlations between variables were modest, indicating that functional recovery after knee arthroplasty does not progress uniformly across all parameters. While improvements in acceleration and turning velocity are clear, the stability of the total execution time suggests that the qualitative aspects of movement—such as fluidity and postural control during turns—may serve as more sensitive long-term recovery indicators than overall speed.

3.4. Effect Size Measures

Cohen's d was used for paired *t*-tests, and effect size r ($Z/\sqrt{n}$) was used for Wilcoxon tests of Collections 1 and 2. The thresholds for interpretation were $\leq$0.20 (minimal effect), 0.20–0.50 (small effect), 0.50–0.80 (moderate effect), and >0.80 (large effect). The results show that the peak velocity during mid-turning had a significant impact ($r = 0.88$), confirming the statistical significance observed ($p = 0.0039$) and indicating a substantial improvement in agility and motor control during intermediate turns.

The peak velocity during end-turning showed a moderate effect ($d = 0.47$), indicating a clinically meaningful improvement in this final turning phase, although it did not reach statistical significance. Transfer variables—both the sit-to-stand duration and anteroposterior acceleration—exhibited minor-to-moderate effects ($r \approx 0.39$), suggesting small but noticeable improvements in the postural transition capacity. Lastly, the total test duration remained essentially unchanged ($d = -0.13$), reinforcing the finding that the overall execution time did not vary significantly between collections.

Taken together, despite the sample size limitation, this effect size analysis shows that the most significant improvements in function occurred in tasks involving changes of direction and dynamic control, which are key for independence in daily activities. Although the overall execution time has consistently been found to be stable in the literature—where qualitative improvements in fluidity and safety may occur before or without changes in the overall task time—the moderate-to-significant effects observed in turning phases highlight the importance of including rotation- and balance-specific exercises in medium- and long-term rehabilitation plans.

The evaluation of turning velocities following unilateral total knee arthroplasty revealed distinct patterns when statistical significance was interpreted alongside the Minimal Clinically Important Difference (MCID). For mid-turning peak velocity, the baseline mean was 106.4°/s (SD 31.0), increasing to 132.8°/s (SD 30.8) at follow-up, corresponding to a mean gain of 26.4°/s. Using a distribution-based method, the MCID was estimated at approximately 15.5°/s (½ SD). The observed improvement not only achieved statistical significance ($p = 0.0039$) but also clearly exceeded the MCID threshold, thereby supporting its clinical relevance. This finding indicates that patients experienced a perceptible enhancement in agility and motor control during turning tasks, which is likely to translate into improved functional mobility and safety in daily activities.

By contrast, end-turning peak velocity demonstrated a more modest change. The baseline mean was 135.4°/s (SD 25.1), increasing to 141.9°/s (SD 22.2), for a mean gain of 6.5°/s. The calculated MCID for this parameter was approximately 12.5°/s. Although the improvement corresponded to a moderate effect size, it did not surpass the MCID threshold, suggesting that the change may not be clinically meaningful despite the apparent trend. This highlights that not all statistically detectable improvements are of practical significance, reinforcing the value of MCID in distinguishing clinically relevant outcomes.

Taken together, these results emphasize the importance of integrating both statistical and clinical perspectives in the interpretation of functional outcomes after total knee arthroplasty. The clinically meaningful improvement in mid-turning velocity underscores the potential for rehabilitation programs to specifically target rotational control and agility, while the limited clinical impact of end-turning gains suggests that further strategies may be required to elicit meaningful benefits in this phase of mobility.

3.5. Test–Retest Reliability and Measurement Error

Pearson's correlation coefficients (r) between the measurements from Collections 1 and 2 ranged from weak to moderate, with higher values observed for the end-turning phase metrics ($r = 0.41$; $R^2 = 0.16$ for phase duration; $r = 0.47$; $R^2 = 0.22$ for peak rotational velocity). In contrast, the stand-to-sit parameters showed weak-to-negligible correlations (r between -0.25 and 0.12; $R^2 < 0.07$). The intraclass correlation coefficients (ICC_2, two-way absolute agreement) were moderate for the end-turning ($ICC_2 = 0.45$–0.49) metrics but low to negligible for the stand-to-sit metrics (ICC_2 from -0.08 to 0.26), indicating limited reproducibility for several variables. The standard error of measurement (SEM) ranged from 0.43 to 9.22 units, indicating notable imprecision, especially in the end-turning peak rotational velocity. Table 3 reports the coefficients of determination (R^2) for all significant correlations. Overall, these results suggest that the end-turning metrics are more consistent and less prone to relative imprecision than the stand-to-sit metrics, highlighting the need to improve sensor acquisition and calibration protocols to enhance repeatability and the clinical relevance of instrumented TUG assessments.

Table 3. Coefficients of determination (R^2) for all significant correlations.

Variable	r	R^2	ICC_2	SEM
End-Turning	0.4061	0.1649	0.4505	0.4313
End-Turning 2	0.4657	0.2169	0.4900	9.2197
Stand-to-Sit.1	−0.2546	0.0648	−0.0771	0.9924
Stand-to-Sit.2	−0.2202	0.0485	−0.0347	1.2127
Stand-to-Sit	0.1229	0.0151	0.2580	0.7221

4. Discussion

This study investigated the progression of functional mobility in patients who underwent unilateral total knee arthroplasty (TKA) through a transquadriciptal approach, assessed at two late postoperative time points (around 18 and 53 months). The main finding was not a change in the total task execution time—which remained consistently around 15 **s** in both assessments—but rather a qualitative improvement in movement. Specifically, a statistically significant, large effect was observed in the peak velocity during the mid-turning phase ($r = 0.88$; $R^2 = 0.77$), along with a clinically relevant, moderate improvement in the end-turning velocity ($r = 0.47$; $R^2 = 0.22$; $ICC_2 = 0.49$; SEM = 9.22). These results indicate that, even though functional recovery typically stabilizes within the first year after surgery, ongoing refinements occur in more complex aspects of motor control, such as agility and dynamic stability [18].

The stability of the overall Timed Up and Go (TUG) test duration—with average values of about 15 s in both assessments—matches that in longitudinal studies showing that, although the biggest functional improvements after TKA occur within the first 12 months, recovery can take up to 2 years, after which performance tends to level off [19]. The average time in our sample is higher than reference values for healthy adults of the same age group (usually under 12 s) [20], indicating that functional deficits remain even years after surgery. A recent systematic review confirmed that TKA patients continue to show poorer performance on functional tests than healthy controls in the long term [13]. These findings support the hypothesis that certain aspects of gait performance—particularly those involving turning and dynamic transitions—may continue to improve beyond the first postoperative year, even when the overall test duration remains unchanged [21].

The most notable finding was the significant increase in turning velocities. The peak mid-turning velocity rose substantially, with a large effect size ($r = 0.88$; $R^2 = 0.77$), indicating a strong improvement in directional change ability. Turning tasks are neuromotorically more challenging than straight-line walking, requiring greater postural control, coordination, and motor planning [22]. The late improvement in this measure suggests ongoing motor learning and proprioceptive adaptation. As described by Maiora et al., the TUG test is a valuable tool for assessing complex functional mobility [21]. Over time, patients may develop more efficient and safer strategies for turning, which is crucial for daily functioning and reducing fall risk, which is a persistent issue in the TKA population [23]. The strong positive correlation ($\rho = 0.60$; $R^2 = 0.36$) between the mid- and end-turning velocities in the second assessment supports the idea that patients adopt a more consistent and effective turning strategy.

Analyses of postural transfers, such as the sit-to-stand (STS) maneuver, showed small-to-moderate improvement trends, though not statistically significant. The moderate negative correlation ($\rho = -0.58$; $R^2 = 0.34$) between sit-to-stand anteroposterior acceleration and the overall TUG duration in the first assessment indicates that generating initial momentum was an important factor early on. The weakening of this relationship in the second assessment may reflect a shift in functional strategy: while explosive strength was key initially, fluidity and dynamic control during turns became the main factors influencing long-term performance quality. Importantly, the STS metrics exhibited low test–retest reliability (ICC_2 = 0.26; SEM = 0.72), suggesting that the observed trends might be within the measurement error and should be interpreted cautiously [23].

Low intraclass correlation coefficient (ICC) values observed for some of the instrumented Timed Up and Go (TUG) measurements in this study warrant careful consideration. Reliability indices such as ICC reflect the consistency of repeated measurements across time, and low values may indicate that variability is not attributable solely to true patient differences, but also to methodological or technical factors. A recent systematic review reported wide variability in intraclass correlation coefficient (ICC) values across iTUG components, ranging from moderate to excellent depending on the segment analyzed and the protocol used, and concluded that the complexity and lack of standardization of extracted measures reduce reliability and validity—particularly for turning and transition phases, where low ICCs were frequently observed [24]. Convergent-validation and test–retest reliability studies corroborate these findings: overall TUG duration and walking phases typically show high reliability (ICC > 0.9), whereas subcomponents such as turning and sit-to-stand/stand-to-sit transitions often exhibit low to moderate ICCs (sometimes < 0.5), implicating technical factors (e.g., segmentation algorithm accuracy and sensor sensitivity) and variability in test execution [25,26]. These results are consistent across diverse populations—including older adults, patients with neurological disorders, and children—highlighting the variable reliability of iTUG subcomponents and the need for greater protocol standardization and improved analysis algorithms [24–27].

One plausible explanation is measurement error, which can arise from several sources. The inertial measurement unit (IMU) used in this study, although validated for functional mobility assessments, may introduce variability due to signal noise, drift in gyroscopic data, or limitations in the sampling frequency. Small deviations in data acquisition or post-processing can accumulate and influence derived kinematic parameters such as acceleration or turning velocities, and measurement error—originating from signal noise, gyroscopic drift, limited sampling frequency, and small deviations during data acquisition or post-processing—can accumulate and materially affect derived kinematic metrics such as acceleration and turning velocities [28]. Together, these observations underscore the need for methodological refinements (e.g., rigorous sensor calibration, drift-compensation algorithms, adequate sampling rates, standardized segmentation and filtering procedures, and transparent post-processing pipelines) to reduce measurement bias and improve the reliability of sensor-based kinematic outcomes.

Another contributing factor may be sensor placement. The IMU was positioned at the L5 vertebral level, following standard protocols, but slight deviations in placement, orientation, or fixation tightness between sessions could alter the accuracy of captured signals. Given that patients were evaluated months to years apart, minor inconsistencies in sensor setup could have impacted reproducibility. There is broad consensus in the literature that small variations in the position, orientation, or fixation of an inertial measurement unit (IMU)—even when standardized protocols are followed—can introduce systematic errors and compromise data reproducibility, particularly for assessments spaced months or years apart. Rigorous standardization of sensor placement and thorough documentation of attachment procedures are therefore recommended to minimize these effects and to improve reliability in longitudinal and multicenter studies [29–32].

In addition, patient-related factors may also contribute. Functional tasks such as sit-to-stand or stand-to-sit involve greater variability in strategy across individuals, which may explain why ICC values were lowest for these parameters. Unlike walking or turning—where motor strategies are relatively consistent—transitional movements are more influenced by compensatory behaviors, fatigue, or fear of instability, leading to greater intra-individual variability. Other studies indicate that postural-transition tasks show greater variability—driven by individual differences and compensatory strategies—which is reflected in lower intraclass correlation coefficients (ICCs) for these parameters compared with gait or turning tasks [33,34].

Finally, the small sample size must be considered, as it amplifies the influence of outliers on reliability statistics. In small cohorts, even a few inconsistent trials can markedly reduce ICC values, underestimating the true reproducibility of the instrumented TUG.

Taken together, the low ICC coefficients likely reflect a combination of technical (measurement error, sensor placement), procedural (longitudinal variability in testing conditions), and patient-related (heterogeneity in movement strategies) factors. Future studies should aim to minimize these sources of variability by standardizing sensor placement protocols, increasing the number of test repetitions, and validating outcomes in larger samples to provide more robust reliability estimates.

These findings have important clinical implications. First, evaluating functional recovery after TKA should go beyond simple time-based measures. Analyzing specific aspects of the task—such as turning phases—with technologies such as IMUs provides a more sensitive view of movement quality, especially as end-turning metrics show moderate reliability ($ICC_2 \approx 0.49$; SEM ≈ 9.22) compared to the low reliability of transition phases. Additionally, our results highlight the need for rehabilitation programs that extend beyond the first year after surgery. These programs should include exercises that improve dynamic postural control, coordination, and agility during directional changes, focusing on enhancing performance in daily activities rather than only the linear gait capacity. No studies identified in the analyzed medical literature significantly refute these findings. On the contrary, available data reinforce the importance of using technologies such as IMUs for a more comprehensive and sensitive assessment of functional recovery after TKA, as well as the need for prolonged and targeted rehabilitation for complex daily functional demands [35].

This study has several limitations that must be acknowledged. First, the small sample size (n = 19) limits its statistical power and generalizability. The lack of a control group—either composed of healthy individuals or patients treated with a different surgical approach—limits the generalizability and interpretability of our findings. As such, it is not possible to determine whether the observed changes are directly attributable to the surgical technique itself or reflect natural functional recovery over time. Moreover, relevant confounding factors such as physical activity levels and adherence to physiotherapy protocols were not consistently recorded in the patients' medical files and were thus not controlled for in this study. However, given the detailed and objective nature of the functional assessments, this case series offers valuable descriptive data to support the design of future comparative studies.

Future research should focus on validating these findings in larger, multicenter cohorts. Comparative studies assessing TUG kinematics after surgery using different approaches (such as transquadriciptal, subvastus, and medial parapatellar approaches) would be especially valuable. Additionally, exploring the relationships between kinematic parameters and other factors—such as quadriceps and hip muscle strength, patient confidence measures, and fall rates—could help clarify the mechanisms behind this late functional improvement.

5. Conclusions

This study shows that, in older adults who underwent unilateral total knee arthroplasty through a transquadriciptal approach, overall performance measured using the Timed Up and Go (TUG) test remained stable between 18 and 53 months post-surgery. However, qualitative movement parameters—specifically turning velocities (mid-turning and end-turning)—demonstrated significant and clinically meaningful improvements [1].

The strong increase in the peak mid-turning velocity, along with the moderate effects in end-turning and postural transfer components, suggests a late and ongoing enhancement in movement fluidity and motor control, which are essential for independence and reducing fall risk [2].

These findings highlight the importance of conducting segmented assessments and using IMUs to monitor subtle functional improvements that traditional time-based metrics might miss. It is advised that physiotherapy protocols extend beyond the first postoperative year and include exercises focused on rotational control and balance. Future multicenter studies with comparative groups are essential to validate and build upon these results.

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Institutional Review Board Statement: The present study adheres to the national ethical guidelines and regulatory standards for research involving human subjects, as established by the Brazilian National Health Council (Ministry of Health) in October 1996 and updated under Resolution 466/2012. Ethical approval was obtained from the Plataforma Brasil Ethics Committee in Anápolis, Goiás (Protocol No. 6.775.127; CAAE 52052421.9.0000.5076) on 19 April 2024. This prospective, observational, comparative study enrolled participants who provided written informed consent, acknowledging that their involvement was voluntary, free of charge, and experimental. All participants received complete information about the study and could withdraw or revoke consent at any time without penalty. Their confidentiality and privacy were rigorously protected by ethical principles. This study was conducted at a tertiary hospital in partnership with a private university, both of which possess the necessary technical infrastructure and institutional support to ensure the successful execution of the project. In particular, a fully equipped motion analysis laboratory—featuring a portable, wireless G-Walk inertial measurement unit (G-Sensor®, BTS Bioengineering®, Garbagnate Milanese, Italy)—was utilized for data collection.

Informed Consent Statement: All participants were given comprehensive information about the study's objectives, procedures, potential risks, and expected benefits. Participation was entirely voluntary, and each individual provided written informed consent, confirming their understanding of this information and their right to withdraw from the study at any time without penalty.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

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Abbreviations

The following abbreviations are used in this manuscript:

G-Sensor	Wearable inertial measurement unit (BTS Bioengineering, Italy)
L5	Fifth lumbar vertebra (sensor placement level)

SPSS	Statistical Package for the Social Sciences (IBM SPSS Statistics)
CAAE	Certificado de Apresentação para Apreciação Ética (Brazilian ethics approval certificate)
SUS	Sistema Único de Saúde (Brazilian Unified Health System)
IA	Inteligência Artificial (artificial intelligence)

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8.6.3 Functional Performance Tests Following Unilateral Total Knee Arthroplasty: Protocol for a Scoping Review.

Trindade AMV, Rezende LP, Parreira RB, Santili C, Oliveira CS. Functional performance tests following unilateral total knee arthroplasty: protocol for a scoping review. J Adv Med Med Res. 2025;37(12):290-8. doi: 10.9734/jammr/2025/v37i126020

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Este protocolo de scoping review tem o objetivo de mapear sistematicamente o uso de testes de desempenho funcional em pacientes submetidos à artroplastia total unilateral de joelho. O protocolo, elaborado segundo a metodologia do Joanna Briggs Institute (JBI) e reportado conforme o PRISMA-ScR, prevê busca abrangente nas bases PubMed, Embase, Scopus, Web of Science e PEDro, além de literatura cinzenta, incluindo adultos após ATJ unilateral em que sejam aplicados o teste de caminhada de 6 minutos (6MWT), teste de caminhada de 2 minutos (2MWT), Timed Up and Go (TUG) e outros testes padronizados de marcha (p. ex., 10-meter walk test). Serão incluídos ensaios clínicos, estudos observacionais e séries de casos (n > 10), com extração detalhada de protocolos (comprimento do percurso, instruções, uso de dispositivos auxiliares), propriedades de medida (confiabilidade, validade, responsividade) e relação com desfechos autorreferidos. Embora não apresente resultados, o protocolo antecipa encontrar grande heterogeneidade na aplicação e no relato desses testes na população com ATJ unilateral, o que justifica a necessidade de padronização dos métodos de avaliação funcional e fundamenta futuras meta-análises e recomendações de reabilitação baseadas em evidências.

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Functional Performance Tests Following Unilateral Total Knee Arthroplasty: Protocol for a Scoping Review

Andrei Machado Viegas da Trindade [a,b,c*], Leonardo Pinheiro Rezende [c], Rodolfo Borges Parreira [d], Cláudio Santili [b] and Cláudia Santos Oliveira [b,d]

[a] Department of Orthopedics Surgery, Municipal Hospital of Aparecida de Goiânia (HMAP), Aparecida de Goiânia- 74936-600, Brazil.
[b] Health Sciences Program, Santa Casa de São Paulo School of Medical Sciences, São Paulo -01221-020, Brazil.
[c] Faculty of Medicine, Evangelical University of Goiás (UniEVANGÉLICA), Anápolis-75083-515, Brazil.
[d] Human Movement and Rehabilitation Graduate Program, Evangelical University of Goiás (UniEVANGELICA), Anápolis 75083-515, GO, Brazil.

Authors' contributions

This work was carried out in collaboration among all authors. Author AMVT designed the study, developed the search strategy, wrote the protocol, and wrote the first draft of the manuscript. Authors LPR and RBP managed the literature searches and contributed to the refinement of the methodology. Author CS and CSO supervised the project and provided critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: andreimachado.uni@gmail.com;*

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ABSTRACT

Aims: To outline a protocol for a scoping review that will systematically map and synthesize the literature on the use of the 6-Minute Walk Test (6MWT), 2-Minute Walk Test (2MWT), Timed Up and Go (TUG) test, and other standardized walk tests for assessing functional performance in patients following unilateral Total Knee Arthroplasty (TKA).
Study Design: Scoping review protocol.
Place and Duration of Study: Not applicable (Literature review protocol).
Methodology: This scoping review will be conducted following the Joanna Briggs Institute (JBI) methodology and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR). A comprehensive search will be performed in PubMed (MEDLINE), Embase, Scopus, Web of Science, and PEDro databases, supplemented by a grey literature search. Two independent reviewers will screen studies for eligibility, extract data, and chart the results. The Population, Concept, and Context (PCC) framework will guide eligibility: adults with unilateral TKA (Population), use of 6MWT, 2MWT, TUG, or standardized walk tests (Concept), in a post-operative.
Results: This is a protocol study; no results are presented at this stage.
Conclusion: The findings from this review are expected to identify the extent and nature of the evidence on functional performance tests in the unilateral TKA population. We anticipate this work will highlight variations in testing protocols, identify research gaps, and provide a foundation for standardizing assessment methods, which is essential for improving the synthesis of clinical trial data and guiding evidence-based rehabilitation practices.

Keywords: Scoping review; total knee arthroplasty; functional performance; 6-minute walk test; timed up and go; rehabilitation; measurement properties.

ABBREVIATIONS

TKA	*: Total Knee Arthroplasty*
6MWT	*: 6-Minute Walk Test*
2MWT	*: 2-Minute Walk*
Test TUG	*: Timed Up and Go test*
PROMs	*: Patient-Reported Outcome Measures*
WOMAC	*: Western Ontario and McMaster Universities Osteoarthritis Index*
KOOS	*: Knee injury and Osteoarthritis Outcome Score*
PRISMA-ScR	*: Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews*
JBI	*: Joanna Briggs Institute*
PCC	*: Population, Concept, and Context framework*

1. INTRODUCTION

Total Knee Arthroplasty (TKA) is a cornerstone of orthopedic surgery, widely recognized as the definitive treatment for end-stage knee osteoarthritis (Hart et al., 2016). The procedure has demonstrated robust efficacy in alleviating pain and restoring fundamental joint biomechanics (Carr et al., 2012; Kurtz et al., 2007). Despite the high degree of surgical standardization, the trajectory of post-operative recovery and functional restoration exhibits considerable patient-to-patient variability with different functional metrics improving at different paces over the first year (Christensen et al., 2023; Trindade et al., 2025).

Consequently, the precise and objective assessment of functional outcomes is of paramount importance, not only for tailoring individual rehabilitation programs but also for benchmarking the effectiveness of different therapeutic protocols across clinical centers (Mizner, 2011). Historically, the evaluation of TKA outcomes has been heavily anchored in Patient-Reported Outcome Measures (PROMs), such as the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) or the Knee injury and Osteoarthritis Outcome Score (KOOS). While indispensable for capturing the patient's subjective experience, recent evidence confirms that PROMs have a weak correlation with objective functional tests, as they assess different constructs of function (Hill et al., 2023; Karimijashni et al., 2025). PROMs are susceptible to the influence of psychological factors, individual pain perception, and statistical ceiling effects, which often results in a disconnect between a patient's reported function and their actual, observable physical performance (Terwee, 2006; Stratford, 2006).

To bridge this gap, performance-based measures have emerged as a critical adjunct, offering an objective and quantifiable evaluation of a patient's true functional capacity (Bade, 2010). In fact, current research suggests that PROMs and performance-based tests should be viewed as complementary tools to be used in combination for a more nuanced and complete characterization of outcomes (Hill et al., 2023). Among the array of performance-based tests, the 6-Minute Walk Test (6MWT), the 2-Minute Walk Test (2MWT), various standardized Walk Tests (e.g., 10-meter walk test), and the Timed Up and Go (TUG) test have become pervasive in clinical practice (Unver, 2015; Podsiadlo & Richardson, 1991). Their widespread adoption is attributable to their low cost, administrative simplicity, and established correlation with the ability to perform activities of daily living, particularly within geriatric and orthopedic populations (Dobson, 2012).

A preliminary survey of the literature, however, reveals a landscape marked by significant heterogeneity in the application and reporting of these tests within the specific context of unilateral TKA (Karimijashni et al., 2025). Methodological variations—including differences in track length, the use of verbal encouragement, and the timing of assessments across acute and chronic post-operative phases—pose substantial challenges to evidence synthesis (Naylor, 2020). A further confounding factor is the common practice in research of aggregating data from both unilateral and bilateral TKA cohorts. Given that bilaterais procedures entail distinct physiological demands and recovery trajectories (Liu et al, 2019), this data pooling may obscure functional recovery patterns unique to the unilateral TKA population.

Therefore, a scoping review is warranted to systematically map and chart the existing body of literature. The principal objective of this review is to identify, synthesize, and catalogue the evidence concerning the utilization of the 6MWT, 2MWT, standardized Walk Tests, and the TUG test in assessing post-operative outcomes in patients who have undergone unilateral TKA. This will involve a detailed examination of the testing protocols employed, the reported psychometric properties of the tests, and their overall clinical utility in this specific patient group.

2. METHODOLOGY

2.1 Study Design

This study protocol delineates a scoping review, a methodological approach selected for its particular suitability in mapping the key concepts, sources of evidence, and research gaps within a complex or heterogeneous field of study (Arksey, 2005). The conduct of this review will adhere rigorously to the framework established by the Joanna Briggs Institute (JBI) for scoping reviews (Peters et al., 2020). The final manuscript will be reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist and guidelines (Tricco, 2018).

2.2 Protocol and Registration

This protocol will be registered prospectively with the Open Science Framework (OSF) to ensure transparency and methodological rigor. The research question and subsequent search strategy have been structured using the Population, Concept, and Context (PCC) mnemonic, as recommended by the JBI (Peters, et al., 2020).

- **Population:** The review will include adult patients (≥18 years of age) who have undergone a primary, unilateral Total Knee Arthroplasty.
- **Concept:** The central concept is the use of specific, performance-based functional tests. These include the 6-Minute Walk Test (6MWT), 2-Minute Walk Test (2MWT), the Timed Up and Go (TUG) test, and other formally standardized walk tests (e.g., 10-meter walk test, 50-foot walk test).
- **Context:** The context is the post-operative assessment of function, encompassing all clinical settings (e.g., inpatient, outpatient, home-based) and all follow-up periods (from immediate post-surgery to long-term monitoring).

2.3 Eligibility Criteria

Studies will be selected based on the following detailed inclusion and exclusion criteria:

Inclusion criteria:

- **Participants:** Studies involving adult human subjects (≥18 years old) who have undergone primary unilateral TKA, typically for conditions such as osteoarthritis or rheumatoid arthritis.
- **Concept:** Studies that utilize at least one of the target functional performance tests (6MWT, 2MWT, TUG, or other standardized timed/distance walk tests) as an outcome measure.
- **Context:** Assessments conducted during the post-operative period.
- **Types of sources:** This scoping review will consider for inclusion randomized controlled trials (RCTs), non-randomized controlled trials, observational studies (including cohort, case-control, and cross-sectional designs), and case series (with n > 10 participants).

Exclusion criteria:

- Studies focusing exclusively on bilateral TKA, unicompartmental knee arthroplasty, or revision TKA.
- Studies in which data from unilateral TKA patients cannot be isolated or disaggregated from a mixed cohort that includes bilateral or revision procedures (Liu et al, 2019).
- Cadaveric studies, animal studies, biomechanical modeling studies, editorials, letters, and conference abstracts without sufficient data.
- Studies that do not use one of the specified functional performance tests as an outcome measure.

2.4 Search Strategy

A comprehensive and systematic search strategy will be executed to identify all relevant published and unpublished studies. The search will be conducted across the following major electronic bibliographic databases from their inception to the present date: PubMed (MEDLINE), Embase, Scopus, Web of Science (Core Collection), and PEDro (Physiotherapy Evidence Database). The search will be limited to studies published in English, Spanish, or Portuguese. The search strategy is designed to be highly sensitive to capture a broad range of relevant literature, with the refinement for the specific PCC framework occurring during the screening stages. The search terms will include combinations of medical subject headings (MeSH), Emtree terms, and free-text keywords related to the population and concept. Below are the detailed search strategies for each database:

PubMed (MEDLINE): (("Arthroplasty, Replacement, Knee"[MeSH] OR "total knee arthroplasty"[Title/Abstract] OR "knee replacement"[Title/Abstract] OR "TKA"[Title/Abstract] OR "TKR"[Title/Abstract])) AND ("Walk Test"[MeSH] OR "6-minute walk test"[Title/Abstract] OR "6MWT"[Title/Abstract] OR "six minute walk test"[Title/Abstract] OR "2-minute walk test"[Title/Abstract] OR "2MWT"[Title/Abstract] OR "two minute walk test"[Title/Abstract] OR "Timed Up and Go"[Title/Abstract] OR "TUG"[Title/Abstract] OR "walking speed"[Title/Abstract] OR "gait speed"[Title/Abstract]) AND ("Postoperative Period"[MeSH] OR "postoperative"[Title/Abstract] OR "surgery"[Title/Abstract] OR "recovery"[Title/Abstract] OR "rehabilitation"[Title/Abstract])

Embase: ('knee arthroplasty'/exp OR 'total knee arthroplasty':ti,ab OR 'knee replacement':ti,ab) AND ('walking test'/exp OR '6 minute walk test':ti,ab OR '6MWT':ti, ab OR '2 minute walk test':ti,ab OR 'timed up and go test':ti,ab OR 'TUG':ti,ab OR 'gait speed':ti,ab) AND ('postoperative period'/exp OR 'postoperative':ti,ab OR 'rehabilitation':ti,ab)

Scopus: (TITLE-ABS-KEY ("total knee arthroplasty" OR "knee replacement" OR "TKA")) AND (TITLE-ABS-KEY ("6-minute walk test" OR "6MWT" OR "2-minute walk test" OR "2MWT" OR "Timed Up and Go" OR "TUG" OR "walk test")) AND (TITLE-ABS-KEY ("postoperative" OR "surgery" OR "recovery" OR "rehabilitation"))

Web of Science (Core Collection): TS= ("total knee arthroplasty" OR "knee replacement" OR "TKA") AND TS=("6-minute walk test" OR "6MWT" OR "2-minute walk test" OR "2MWT"

OR "Timed Up and Go" OR "TUG" OR "walk test" OR "gait speed") AND TS= ("postoperative" OR "recovery" OR "rehabilitation")

PEDro (Physiotherapy Evidence Database): Given the limitations of the PEDro advanced search interface, a multi-step search process will be employed using combinations of keywords in the simple search bar. The following search queries will be executed independently:

- knee arthroplasty walk test
- knee arthroplasty timed up and go
- knee arthroplasty 6MWT

2.5 Searching Other Resources (Grey Literature)

To mitigate publication bias and locate relevant studies not indexed in the main bibliographic databases, a comprehensive search of grey literature will be conducted (Paez, 2017). This will include searching Google Scholar (reviewing the first 100 most relevant results), ProQuest Dissertations and Theses Global, and relevant institutional repositories. Furthermore, major clinical trial registries, including ClinicalTrials.gov and the World Health Organization's International Clinical Trials Registry Platform (ICTRP), will be searched to identify ongoing or recently completed studies.

2.6 Source Selection

The selection of sources will be a two-stage process conducted by two independent reviewers to minimize selection bias. First, all retrieved citations will be imported into the Rayyan web application, a tool designed for managing systematic reviews. The two reviewers will independently screen the titles and abstracts of all citations based on the pre-defined eligibility criteria. A pilot screening of 50 randomly selected citations will be performed initially to ensure calibration between the reviewers, aiming for an inter-rater agreement (Cohen's kappa) of >0.80. Any disagreements during the screening process will be resolved through discussion or, if consensus cannot be reached, through arbitration by a third senior reviewer. In the second stage, the full texts of all potentially relevant articles will be retrieved and independently assessed by the same two reviewers against the full eligibility criteria. A standardized form will be used to document the reason for the exclusion of any full-text article. Disagreements at this stage will again be resolved by discussion or third-party arbitration. The entire selection process will be documented and presented in a PRISMA-ScR flow diagram (Tricco et al., 2018).

2.7 Data Extraction and Charting

A data charting form will be developed collaboratively by the research team using a spreadsheet program. The form will be piloted on a sample of 5-10 included studies to refine the variables and ensure clarity and consistency. Two reviewers will independently extract data from each included study. The extracted data will include:

- **Study characteristics:** Author(s), year of publication, country of origin, study design.
- **Population demographics:** Sample size, age (mean and standard deviation), sex distribution, body mass index (BMI), and pre-operative functional status.
- **Intervention details:** Specifics of the unilateral TKA procedure, if available.
- **Functional test protocols:** Detailed information on the administration of each test, including track length, verbal instructions and encouragement provided, number of trials, and use of assistive devices.
- **Outcomes and key findings:** The primary outcomes will be the results of the functional tests (e.g., distance walked in meters for the 6MWT, time in seconds for the TUG). We will also extract data on reported psychometric properties (e.g., reliability, validity, responsiveness) and any correlations reported between the performance-based tests and other measures, such as PROMs.

2.8 Synthesis of Results

Given that the primary goal of a scoping review is to map the literature, a formal meta-analysis will not be conducted. Instead, the extracted data will be synthesized and presented in a descriptive format. The results will be organized thematically and presented in tables and charts to map the evidence according to the functional test type, the timing of post-operative assessment, and the reported outcomes. This narrative synthesis will summarize the breadth and nature of the literature, identify common methodological approaches, and highlight significant gaps in the current evidence base. While a formal risk-of-bias assessment is not a mandatory component of scoping reviews (Arksey, 2005), we will use the appropriate JBI Critical Appraisal Tools to assess the methodological quality of the included studies. This appraisal will not be used to exclude studies but rather to provide context on the overall quality of the evidence in the field.

3. ANTICIPATED OUTCOMES

This scoping review protocol has been designed to comprehensively map the existing literature on the use of key functional performance tests in the unilateral TKA population. By systematically charting the evidence on the 6MWT, 2MWT, TUG, and other standardized walk tests, we aim to provide a clear overview of how these crucial assessment tools are being applied in research and clinical practice.

We expect the findings will reveal significant heterogeneity in testing protocols, including variations in patient instructions, track layouts, and the timing of post-operative assessments. Such inconsistencies, extensively documented in recent systematic reviews (Karimijashni et al, 2025, Konnyu et al, 2023), represent a major barrier to the synthesis of evidence, particularly for future meta-analyses, and may limit the generalizability of study findings (Bennell et al, 2011, Migliorini et al, 2024). Recent systematic reviews have continued to highlight this considerable variability in the types of performance-based tests used, underscoring the need for a clear content analysis to guide selection (Karimijashni et al, 2025, Capin et al 2022). The review will also explore the relationship between these objective, performance-based measures and the more subjective proms. Understanding the degree of correlation—or lack thereof—is critical for developing a holistic and accurate picture of patient recovery (Mizner et al, 2011; Singh et al, 2025). Evidence continues to suggest a weak correlation between these two types of measures, as they evaluate different aspects of function, with proms often being more influenced by pain than by objective performance (Karimijashni et al, 2025; Singh et al, 2025). Indeed, recent meta-analyses confirm that while self-reported function shows clinically meaningful improvements within the first 3 to 6 months, these gains are not consistently matched by performance-based metrics, which often show no significant improvement at any time point (Orange et al, 2025).

By charting the reported psychometric properties of these tests within the unilateral tka context, this review will also provide valuable information for clinicians and researchers seeking to select the most appropriate and robust measures for their specific needs. The ongoing validation of these instruments, such as the recent work on predictive models for the 6mwt and the evaluation of promis cats, confirms their reliability and importance in the clinical setting (Monisha et al, 2025; Dhollander et al, 2025; Kubo et al, 2024). However, significant variability in thresholds for what constitutes a clinically important difference (mcid) persists, complicating cross-study comparisons and highlighting the need for condition-specific benchmarks (Migliorini et al, 2024). Ultimately, the results of this scoping review are intended to serve as a foundational resource. We will identify not only what is known but, more importantly, what is not known, thereby highlighting critical gaps in the literature. The synthesis of findings will inform recommendations for the standardization of functional assessment protocols, suggest directions for future primary research, such as targeted prehabilitation for at-risk patients (Karimijashni et al, 2025), and contribute to the broader goal of optimizing rehabilitation strategies and improving long-term outcomes for patients undergoing unilateral TKA (Bennell et al, 2011; Mizner et al, 2011).

4. CONCLUSION

This scoping review is poised to comprehensively characterize the extent and methodological nature of the evidence regarding functional performance tests—specifically the 6MWT, 2MWT, and TUG—within the unilateral Total Knee Arthroplasty population. We anticipate that the findings will unveil significant heterogeneity in administration protocols and reporting standards, which currently serves as a barrier to effective data synthesis and cross-study comparison. By meticulously identifying these inconsistencies and mapping critical research gaps, this protocol will lay the necessary groundwork for the future standardization of assessment methods. Ultimately, this work aims to facilitate more robust meta-analyses and empower clinicians with high-quality, evidence-based insights to optimize rehabilitation strategies and enhance functional outcomes for patients undergoing unilateral procedures.

CONSENT

It is not applicable.

ETHICAL APPROVAL

Research ethics approval is not required for this study as it involves the review of existing literature and publicly available data. The findings of this scoping review will be disseminated through publication in a peer-reviewed journal and conference presentations.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors declare the utilization of GPT-4 to assist in the linguistic refinement of this manuscript. The tool was employed exclusively to enhance the grammatical accuracy and readability of the text, which was originally drafted in Brazilian Portuguese and subsequently translated into English. The AI's contribution was strictly limited to stylistic and linguistic improvements, without generating new content or altering the scientific substance. Specifically:

1. Following the initial translation from Brazilian Portuguese, the AI was tasked with polishing the English text to ensure consistency with conventional academic usage.

2. Targeted prompts were issued to rectify grammatical inaccuracies and uphold the formal tone required for scientific publication.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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8.6.4 Functional Mobility Assessment after Unilateral Knee Arthroplasty: A Comparative Study of Two Prosthesis Types.

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Estudo prospectivo, observacional e comparativo para avaliar a mobilidade funcional de pacientes submetidos à artroplastia total unilateral de joelho com dois tipos de prótese (platô tibial fixo versus plataforma rotatória). Trinta e seis pacientes (21 mulheres; idade média 69 anos; IMC médio 30,5 kg/m²) foram avaliados em dois momentos, entre 12 e 24 meses de pós-operatório, por meio do teste Timed Up and Go (TUG) instrumentado com sensor inercial G-WALK®, que forneceu 15 variáveis de mobilidade funcional. O tempo total do TUG apresentou leve aumento entre as avaliações (14,47 ± 3,03 s para 15,24 ± 3,85 s), sem significância estatística (P=.301), assim como não houve diferença global entre os tipos de prótese (P=.456). Observou-se melhora significativa na fase de levantar-se (sit-to-stand), com redução do tempo de execução (P=.036), e na fase de giro, com diminuição da duração e aumento da velocidade de rotação (P

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Functional Mobility Assessment after Unilateral Knee Arthroplasty: A Comparative Study of Two Prosthesis Types

Leonardo Pinheiro Rezende [a*], Andrei Machado Viegas Trindade [b], Helder Rocha da Silva Araujo [b], Marcelo Rodrigues Torres [b], Ulric Araújo Vitória [a], Rodolfo Borges Parreira [b] and Cláudia Santos Oliveira [b]

[a] *School of Medicine, Evangelical University of Goiás (UniEVANGÉLICA), Brazil.*
[b] *Master's and Doctoral Program in Health Sciences, Faculty of Medical Sciences, Santa Casa de São Paulo (FCMSCSP), Brazil.*

Authors' contributions

This work was carried out in collaboration among all authors. Author LPR was responsible for writing and submitting the present work to the journal and the Brazilian ethics committee. Author AMVT was responsible for guiding the structure of the article. Author UAV assisted in patient data collection, and author RBP was responsible for statistical analysis. Author CSO provided guidance from the project's conception. All the authors have read the final manuscript and agreed with all the relevant information included in the work. Authors HRSA and MRT were responsible for reviewing the work before its submission by the corresponding author. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: leonardorezende4@gmail.com;*

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ABSTRACT

Aims: To evaluate and compare the functional mobility of patients undergoing unilateral knee arthroplasty using two prostheses: fixed tibial plateau and rotating platform. This study addresses a gap in the existing literature by providing detailed insights into functional mobility patterns and prosthesis-specific outcomes.

Study Design: A prospective, observational, and comparative study with assessments conducted at two-time points: 12 to 24 months after surgery.

Place and Duration of Study: Conducted at a tertiary hospital for rehabilitation and readaptation, in partnership with a private university from March 2022 to December 2024.

Methodology: Thirty-six patients who had previously undergone unilateral knee arthroplasty were included, equally divided between fixed and rotating platform prostheses. The Timed Up and Go (TUG) test, performed with the G-WALK inertial sensor, captured 15 functional mobility variables across two time points. Statistical analyses included variance tests and correlations to identify changes between time points and groups.

Results: The mean TUG time increased from 14.47 ± 3.03 seconds to 15.24 ± 3.85 seconds without statistical significance (*P*=*.301*). However, the Sit-to-Stand phase significantly reduced duration (*P*=*.036*). The turning phase demonstrated significant improvements in both duration (*P*<*.001*) and speed (*P*<*.001*). No statistically significant differences were observed between prosthesis types in most variables. The comparison between fixed and rotating platform prostheses is clinically important as it provides insights for tailoring postoperative rehabilitation strategies.

Conclusion: Fixed and rotating platform prostheses demonstrated comparable functional performance, with specific improvements noted over time. The findings emphasize the value of inertial sensors in conducting detailed clinical assessments and suggest opportunities for further research to enhance prosthesis selection and rehabilitation protocols. This study contributes to clinical practice by offering evidence that supports personalized rehabilitation strategies.

Keywords: Gait analysis; physical functional performance; postoperative period; rehabilitation.

1. INTRODUCTION

Knee osteoarthritis is characterized by structural modifications of the articular cartilage subchondral bone and other anatomical structures, such as Hoffa's fat pad, synovium, ligaments, and muscles. It is the most common progressive musculoskeletal condition (Primorac et al. 2020). Etiology can be divided into primary and secondary causes. Primary causes are often poorly defined, involving genetic factors, chronological age-related changes, ethnicity, and biomechanical factors. Secondary causes include post-traumatic, dysplastic, infectious, inflammatory, or poorly understood biochemical etiologies or a combination of these (Rošin et al. 2024). Knee osteoarthritis leads approximately 10% of individuals around the age of 60 to physical disability, directly impacting their functionality and quality of life (Primorac et al. 2020).

This condition causes pain, functional limitations, and a consequent decrease in quality of life, being a significant cause of functional limitation worldwide (Wojcieszek et al. 2022). Moreover, patients with knee osteoarthritis (OA) represent one of the leading causes of disability, significantly impacting mobility and daily quality of life, highlighting the importance of conducting studies on this pathology, especially considering its significant impact on daily mobility and quality of life (Walankar, Panhale & Koli 2018). Treatment involves conservative therapies, including rehabilitation, physical therapy, medication, and surgical therapies such as osteotomy, arthroscopy, and knee arthroplasty (Wang & Ma. 2022). Knee arthroplasty is considered a safe, cost-effective, and efficient surgical treatment method for knee osteoarthritis (Wang & Ma 2022). Regarding projections for the number of arthroplasty procedures performed, in the United States, more than 500,000 total knee arthroplasties (TKAs) are performed annually to relieve pain associated with OA, with future projections indicating that by 2030, over 3.48 million TKAs will be performed annually (Kurtz S. 2007).

When opting for surgical treatment with knee arthroplasty, the surgeon must determine during the preoperative evaluation the type of knee prosthesis appropriate for the patient's case, considering factors such as the need for greater or lesser prosthesis constraint, tibial plateau mobility, preservation or sacrifice of the posterior cruciate ligament, and fixation with or without cement to ensure joint congruence and more excellent resistance to stress and weight (Lan S. 2024). However, objective gait assessments are not part of routine clinical evaluations, and numerical outcome measures do not sufficiently capture gait difficulties in osteoarthritis, complicating the objective medical analysis of the patient's condition (Boekesteijn et al. 2021).

The postoperative period of knee arthroplasty also influences performance improvement, whether in terms of patient perception or outcome evaluation tests, using quality-of-life indices, gait speed, and knee range of motion, particularly from one year postoperatively (Freijo, Navarro e Villalba, 2024). Some authors indicate that knee arthroplasty restores lower limb function, with significant improvements in gait and balance after three months postoperatively, without additional improvement or balance changes beyond this period, considering only the Timed Up and Go and single-leg support tests (Tsubosaka et al. 2020).

We hypothesize that patients undergoing knee arthroplasty will show changes in functional mobility, especially in the knee joint with the prosthesis, and that these changes will become progressively evident over time. Characterizing functional mobility in this population using inertial sensors has practical implications as a basis for proposing surgical approaches tailored to prostheses that have less impact on improving functional mobility. This approach is scarcely available in the current scientific literature despite the prevalence of articles using self-reported assessment tests to establish postoperative outcomes of knee arthroplasty, which have limitations as they are based on patient perception (Youn et al. 2020). An alternative approach involves measuring outcomes based on performance, such as the 6-minute walk test (6MW) and Timed-Up-and-Go (TUG) (Iwata et al. 2024).

This study compares functional mobility in patients undergoing unilateral knee arthroplasty with fixed and rotating prostheses using the Timed Up and Go (TUG) test. Statistical analysis will also characterize the functional mobility patterns of patients undergoing posterior-stabilized knee arthroplasty with a fixed tibial plateau base and posterior-congruent knee arthroplasty with a rotating tibial plateau. Finally, it offers the possibility to compare the functional mobility patterns of patients who underwent the two types of prostheses. This is particularly important given the limited number of publications evaluating and comparing functional mobility using a follow-up approach in patients undergoing unilateral knee arthroplasty with different prosthesis types.

2. METHODOLOGY

The patients were selected from a tertiary hospital in Goiás, Brazil. The sample for this preliminary study consisted of 36 patients who had previously undergone total knee arthroplasty. The sample size was determined based on the results of a repeated measures analysis of variance by Tsubosaka et al. (2020), with a minimal difference between treatment means of 0.2, a standard deviation of 0.3, a test power of 80%, and an alpha of 0.05. The total sample size estimated for definitive results was established at 54 patients.

The patient assessment was carried out following approval from the Ethics and Research Committee. It involved a screening and evaluation protocol in which patients were assessed using the Timed Up and Go (TUG) test. Participants were informed about any potential discomfort or risks associated with the study. Initially, the research posed minimal risks to participants; however, given its multidisciplinary nature—encompassing Orthopedics and Physical Therapy—subjects might experience some discomforts, such as muscle fatigue, falls, or cramps during the evaluation.

In the event that participants experience discomfort during the research, they will be referred to the outpatient clinic, where they will receive care in accordance with the institution's procedures and regulations, as established in agreement with the institution's director. Given that the evaluation procedures in the fields of orthopedics and physical therapy are non-invasive, protective measures have been implemented to minimize risks, including allowing patients adequate time to acclimate to the laboratory environment and the professionals involved.

If patients experienced muscle fatigue or cramps at any point during the evaluations, the assessments would be paused. To reduce the risk of falls, the tests were carried out in suitable locations, supervised by experienced professionals available to provide immediate medical assistance if necessary. The evaluations were conducted by specialists in orthopedics and physical therapy. During the motor assessments, participants were accompanied by at least one volunteer along with a professional, who remained by their side throughout the evaluation process.

2.1 Eligibility Criteria

For the inclusion criteria, individuals must be classified as having advanced knee osteoarthritis with a Kellgren and Lawrence classification of ≥4, aged between 50 and 80, and having undergone their first surgery for osteoarthritis. Regarding the exclusion criteria, individuals must not present neurodegenerative diseases, secondary osteoarthritis, previous knee surgery, a history of knee fracture within the last 12 months, hip arthroplasty, a history of pre- or post-operative infection, comorbidities that impair proper recovery and post-operative rehabilitation, or a history of knee revision arthroplasty.

2.2 Patient Assessment

The evaluation process was conducted with a maximum duration of 30 minutes daily. Subjects were assessed using an inertial sensor (G-Walk) during the TUG test. Throughout the test procedure, this sensor captured and stored all 15 variables related to functional mobility parameters. The average of three TUG measurements was taken. The assessment was performed at two-time points: an initial post-surgical evaluation (on average 12 months after surgery) and a second evaluation two years after the surgical intervention. An identification form was initially completed, and anthropometric data were measured (body mass, height, and body mass index).

The Timed Up and Go (TUG) test analyzed functional mobility parameters. This test quantifies, in seconds, the time it takes for an individual to perform a task consisting of standing up from a standardized chair without armrests, walking three meters, turning around, walking back toward the chair, and sitting down again (Maiora et al. 2024). Subjects were instructed to perform the test at a self-selected, safe pace to avoid the risk of falling. The test was performed twice, with the first serving as familiarization. Data was collected using a portable G-sensor positioned at the L5 vertebra level. This is a wireless inertial sensor system designed for human motion analysis.

The sensors are controlled by a data recording unit (up to 16 elements) via ZigBee radio communication. Each sensor has dimensions of 62mm × 36mm × 16mm, a weight of 60g, and is composed of a three-axis accelerometer (maximum scale of ±6g), a three-axis gyroscope (full scale of ±300°/s), and a three-axis magnetometer (full scale of ±6 Gauss). This device is calibrated with gravitational acceleration immediately after manufacturing. For this study, only one device was used, collecting data at a sampling frequency of 50 Hz. The inertial sensor data were transmitted via Bluetooth to a computer and processed using proprietary software (BTS G-STUDIO, version 2.6.12.0), automatically providing the parameters (Studio Idee Material 2024).

2.3 Statistical Analysis

Descriptive statistics were provided using the mean, standard deviation, median, and interquartile range. A two-factor analysis of variance (ANOVA) was performed to compare differences between prosthesis types (dependent variable) and the TUG test (independent variable). In cases of sphericity violation, values were adjusted using a base-10 logarithm, and if violations persisted, the Kruskal-Wallis test was applied. A t-test or Mann-Whitney test, in the case of non-parametric data, was used to compare independent variables between prosthesis types. The relationship between functional mobility, postoperative time, and prosthesis type was analyzed using Pearson's correlation test or Spearman's correlation test or its non-parametric counterpart. Analyses were conducted using the SPSS statistical software version 19 (IBM), considering a p-value ($P<.05$) as the threshold for statistical significance.

3. RESULTS AND DISCUSSION

Data collection was conducted with research participants, and the sample was characterized according to the data presented in Table 1. The analysis of the results revealed that the average time for the Timed Up and Go (TUG) test increased from 14.47 ± 3.03 seconds to 15.24 ± 3.85 seconds. However, this change was not statistically significant according to Wilk's Lambda test for the collection time factor ($P=.301$) and the type of prosthesis used ($P=.456$). This suggests that although there was an increase in the time required to perform the TUG, the observed differences over time or between prosthesis types (fixed and rotating) were not sufficiently large to be considered statistically significant.

In the Sit-to-Stand phase, which assesses the movement of standing up from a seated position, a decrease in the duration of this movement was observed, from 1.83 ± 0.40 seconds to 1.66 ± 0.42 seconds. This reduction was statistically significant over time (*P=.036*), indicating an improvement in the efficiency of this movement over time. However, no significance was found regarding the type of prosthesis used (*P=.134*) or between the groups with fixed and rotating prostheses (*P=.665*). Additionally, the anterior-posterior acceleration in this phase decreased from 4.08 ± 1.79 m/s² to 3.69 ± 2.24 m/s², with no significant difference for the collection time (*P=.348*), the type of prosthesis (*P=.278*), or between the groups (*P=.263*).

The mediolateral velocity in the Sit-to-Stand phase also decreased from 2.03 ± 0.82 m/s² to 1.82 ± 0.88 m/s². Although this reduction was noteworthy, no significant difference was observed for time (*P=.287*), the type of implant (*P=.095*), or between the groups (*P=.984*). The vertical velocity in this phase decreased from 4.55 ± 1.91 m/s² to 3.95 ± 1.96 m/s², with no statistical significance for time (*P=.090*), the type of prosthesis (*P=.604*) or between the groups (*P=.286*).

In the Stand-to-Sit phase, which assesses the movement of sitting down, the duration increased from 2.09 ± 0.39 seconds to 2.15 ± 0.93 seconds, again without significant differences for time (*P=.682*), the type of prosthesis (*P=.086*), or between the groups (*P=.513*). The anterior-posterior acceleration in this phase decreased from 3.51 ± 1.30 m/s² to 3.25 ± 0.94 m/s², with no significance for time (*P=.368*), the type of implant (*P=.700*), or between the groups (*P=.648*). The mediolateral velocity decreased from 3.65 ± 1.36 m/s² to 3.03 ± 1.31 m/s², with a significant difference for time (*P=.026*) but no significance for the type of implant (*P=.292*) or between the groups (*P=.820*). Additionally, vertical acceleration increased from 4.60 ± 2.03 m/s² to 5.42 ± 2.43 m/s², with a trend toward significance for time (*P=.065*) but no significant difference for the type of implant (*P=.371*) or between the groups (*P=.762*).

The rotation phase, which assesses the turning movement, showed a decrease in average duration from 3.45 ± 0.90 seconds to 2.57 ± 0.77 seconds, with a significant difference for time (*P<.001*) and for the type of implant (*P=.017*). However, no significant difference was observed between the types of implants (*P=.409*). The rotation speed increased from 54.62 ± 12.12°/s to 68.74 ± 17.71°/s, with clear statistical significance for time (*P<.001*) but no significant difference for the type of implant (*P=.327*) or between the groups (*P=.743*).

In the final rotation phase, the duration decreased from 2.48 ± 0.79 seconds to 2.23 ± 0.49 seconds, with a trend toward significance for time (*P=0.056*) and the type of implant (*P=.053*), but no significant difference between the groups (*P=.155*). Finally, the average rotation speed in the final phase increased from 68.03 ± 15.38°/s to 75.13 ± 13.81°/s, with a significant difference for time (*P=.008*) and a trend toward significance for the type of implant (*P=.057*). However, no significant difference was observed between the groups (*P=.316*).

Table 1. Characterization of the sample of patients participating in the study

Participants	Total	36
Sex	Female	21
	Male	15
Average Age	69,38 years	
Average Weight	77,8 kg	
Average Height	1,60m	
Average BMI	30,46	
Laterality	Right	24
	Left	12
Implant	Fixed Plateau	18
	Rotating Plateau	18
Average Postoperative Period (1°st Evaluation)	17,31 meses	
Average Postoperative Period (2°st Evaluation)	42,80 meses	

The results demonstrate that, while some significant changes were observed over time in specific phases and variables, differences between fixed and rotating prostheses were generally not statistically significant, indicating similar functional performance. Notably, the significant improvement in the Sit-to-Stand phase suggests enhanced ability in daily activities like transitioning from sitting to standing, directly benefiting independence and quality of life. Similarly, improved rotation speed reflects better dynamic stability, potentially reducing fall risks. The comparable outcomes between prosthesis types emphasize optimizing rehabilitation strategies over prioritizing specific prostheses. These findings support the development of targeted interventions to address functional deficits, such as mediolateral velocity or vertical acceleration, for improved mobility and patient outcomes.

The results demonstrate the complexity of functional adaptations following total knee arthroplasty (TKA). While the improvement in the efficiency of movements such as Sit-to-Stand was significant over time, other parameters, such as the total time for the Timed Up and Go (TUG) test, did not show statistically significant differences. This lack of significance, coupled with reported functional difficulties in daily activities such as climbing stairs or getting in and out of vehicles (Berghmans et al. 2018), suggests that postoperative gains may not fully meet these patients' daily demands.

The data reinforce the importance of precise and comprehensive measurements to evaluate the impact of TKA. The analysis of spatiotemporal and kinematic parameters, such as the duration of specific phases and accelerations in different directions, is essential for a detailed understanding of gait in patients undergoing this surgical intervention. Previous studies show that inertial sensors provide measurements comparable to optoelectronic and electro-electronic systems, widely regarded as the gold standard (Kobsar et al., 2020). This opens new possibilities for large-scale clinical assessments at lower costs, especially in settings that lack sophisticated equipment (Boekesteijn et al. 2022).

However, gait analysis in laboratory settings may be influenced by factors such as the Hawthorne effect, which describes changes in behavior due to direct observation by researchers (Akgülle et al.,2022). This interference can be particularly relevant for gait studies, where direct observation may lead to unnatural movement patterns. Thus, the difference between daily and laboratory gait is a limitation that must be considered when interpreting results. Future studies could benefit from data collection in more natural environments, such as using inertial sensors under real-life conditions, to assess functional performance more representatively.

The findings also align with systematic reviews that have identified slower gait speed, shorter step length, and shorter stride duration in individuals with knee or hip osteoarthritis (OA) compared to healthy controls (Ritsuno et al. (2023). These gait alterations are consistent with the functional limitations observed in post-TKA patients, even when some parameters show improvements over time, such as in the Sit-to-Stand or rotation phases. However, the absolute values of these changes in many cases remain below the minimum detectable thresholds reported in the literature, such as those established by TUG, 6MW, and SCT (King et al. 2022). This reinforces that while some changes are statistically significant, their clinical relevance may be questionable.

Another important point is the similarity between the performances of fixed and rotating prostheses. The results show that, despite statistically significant differences in some variables, such as the duration of the rotation phase, the prostheses tend to exhibit comparable functional performances. This equivalence between different prostheses reflects technological advances in the field, indicating that both can be effective in functional rehabilitation, depending on other factors such as surgical preferences or patient adaptations (Boekesteijn et al. 2022).

Finally, a recognized limitation of this study was the lack of complete data for all participants, which may reduce the statistical power of the analyses. However, as mentioned, the analysis of the subset with complete data did not reveal systematic bias. Moreover, functional recovery should not be evaluated solely based on objective parameters. Perceptions of pain, function, motivation, and psychological state are essential factors that influence recovery and vary significantly between individuals. A comprehensive understanding of functional recovery after TKA requires a multifaceted approach that combines objective measures with subjective assessments to capture the nuances of each patient's experience (Boekesteijn et al. 2022).

The small sample size of this study, comprising 36 participants equally divided between the two prosthesis types, presents limitations in the reliability and generalizability of the findings. A smaller sample reduces statistical power, increasing the likelihood of Type II errors, where meaningful differences may not be statistically significant. Furthermore, it limits the ability to detect nuanced differences between subgroups, particularly when analyzing variables with higher variability. This constraint may also hinder the extrapolation of results to a broader population, as the observed outcomes may not fully represent the diversity of patient responses to unilateral knee arthroplasty. Despite this limitation, using advanced measurement tools, such as inertial sensors, ensures that the data collected is precise and detailed, providing valuable insights. Future studies with larger sample sizes would enhance the robustness of these findings and allow for more definitive conclusions regarding functional performance and the comparative efficacy of fixed and rotating prostheses.

4. CONCLUSION

The results of this study highlight the complexity of functional adaptations following total knee arthroplasty (TKA). While a significant improvement in movement efficiency during the Sit-to-Stand phase was observed over time, other parameters, such as the total time for the Timed Up and Go (TUG) test, did not show statistically significant differences. Additionally, fixed and rotating prostheses demonstrated comparable functional performances, with no significant differences in most analyzed variables.

The analysis also indicated significant changes during the rotation phase, with a reduction in duration and increased rotation speed, suggesting specific improvements over time. However, other variables, such as accelerations and velocities in different directions during the Sit-to-Stand and Stand-to-Sit phases, showed trends toward significance or did not exhibit statistically relevant changes.

The study's limitations include incomplete data for all participants, potentially reducing statistical power, though no systematic bias was identified. A multifaceted evaluation integrating objective and subjective measures, such as pain perception, motivation, and psychological state, is recommended. Future research could increase the sample size to detect minor differences, include more diverse populations for broader applicability, and integrate patient-reported outcomes for a holistic view of recovery. More extended follow-up periods provide insights into long-term adaptations, while real-world activity monitoring with wearable sensors could enhance ecological validity and address laboratory limitations. These modifications would strengthen the study's robustness and clinical relevance.

The study ultimately underscores the promise of inertial sensor-based technologies for conducting extensive clinical measurements in real-world settings, providing benefits in terms of cost and accessibility. These findings enhance our understanding of the limitations and possibilities for functional recovery following total knee arthroplasty (TKA), highlighting the need for personalized and holistic approaches to rehabilitation. Future research should incorporate both subjective and objective assessments to gain a more comprehensive insight into functional recovery after knee arthroplasty.

ETHICAL APPROVAL AND CONSENT

The present study complies with the guidelines and regulatory standards for research involving human beings, formulated by the national health council of the ministry of health, established in october 1996 and updated in resolution 466 in 2012, in brazil. The study was conducted after approval by the ethics committee Platform Brazil, Anápolis, Goiás, under protocol number 6.775.127 and caae certification number: 52052421.9.0000.5076. This is a prospective, observational, and comparative study in which all participants agreed to their participation by signing an informed consent form, acknowledging that the procedure they underwent was voluntary, free of charge, and experimental.

All participants had access to all relevant information and were permitted to withdraw from the research or revoke their consent at any time without any prejudice or harm. Additionally, the absolute confidentiality of participants' identities was ensured, based on ethical principles of confidentiality and privacy. The study was carried out at tertiary hospital in partnership with a private university possesses the technical and infrastructural capacity, as well as sufficient institutional support, to ensure the successful completion of the project. This included a fully equipped motion analysis laboratory with the portable and wireless g-walk inertial sensor (gsensor, bts bioengineering s.p.a., italy).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors acknowledge the use of GPT-4 for rewriting and editing this manuscript, specifically for refining the English grammar of the translated text, which was originally written in Brazilian Portuguese. The AI's role was strictly limited to improving the grammatical accuracy and ensuring alignment with academic language standards, without adding any new information to the text. The details of AI usage are as follows:

1. The original manuscript, written in Brazilian Portuguese, was translated into English, and AI was employed to enhance the grammatical quality of the final version, adhering to academic English conventions.
2. Carefully designed prompts were used to guide the AI in making grammatical corrections and verifying the translation's consistency with academic norms.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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8.6.5 Biomechanical Assessment of Patients with Unilateral Total Knee Arthroplasty: A Preliminary Comparative Study.

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Estudo prospectivo, observacional e comparativo para investigar diferenças biomecânicas entre dois tipos de prótese na artroplastia total unilateral de joelho: prótese posterior-estabilizada com base tibial fixa e prótese congruente com platô tibial rotatório. Trinta e seis pacientes (21 mulheres; idade média 69,4 anos; IMC médio 30,5 kg/m²) foram avaliados em duas ocasiões entre 12 e 24 meses de pós-operatório por meio do teste de caminhada de 2 minutos (2MWT) instrumentado com sensor inercial G-Sensor® (BTS Bioengineering), que permitiu extrair variáveis espaciotemporais de marcha e simetrias pélvicas. A ANOVA de dois fatores não identificou diferenças significativas entre tipos de prótese ou entre lado operado e não operado para fase de apoio, duplo apoio, apoio simples, fase de balanço, ciclo da marcha, comprimento de passo, cadência, velocidade e índices de simetria pélvica ($p>0,05$), indicando desempenho funcional global semelhante entre os implantes. Análises de correlação mostraram, no grupo com platô rotatório, forte correlação negativa entre tempo de teste e cadência/velocidade ($r \approx -0,67/-0,66$), enquanto no grupo com platô fixo a correlação forte ocorreu apenas entre tempo e velocidade ($r=-0,80$) e observou-se correlação negativa entre cadência e rotação pélvica. Os autores concluem que ambos os desenhos protéticos restauram de forma equivalente a mobilidade após ATJ unilateral e reforçam a aplicabilidade do 2MWT associado a sensores inerciais como ferramenta objetiva para monitorar o desempenho funcional nessa população.

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Biomechanical Assessment of Patients with Unilateral Total Knee Arthroplasty: A Preliminary Comparative Study

Andrei Machado Viegas Trindade [a], Leonardo Pinheiro Rezende [b*], Cícero Antônio Dos Santos Júnior [c], Elias Santos Coimbra Batista [c], Fernanda Ribeiro Garcia [c], Gabriel Souza Camargo [c], Rodolfo Borges Parreira [b] and Cláudia Santos Oliveira [a]

[a] *Master's and Doctoral Program in Health Sciences, Faculty of Medical Sciences of Santa Casa de São Paulo (FCMSCSP), Brazil.*
[b] *School of Medicine, Evangelical University of Goiás (UniEVANGÉLICA), Brazil.*
[c] *School of Physiotherapy, Evangelical University of Goiás (UniEVANGÉLICA), Brazil.*

Authors' contributions

This work was carried out in collaboration among all authors. Author LPR was responsible for writing and submitting the present work to the journal and the Brazilian ethics committee. Author AMVT was responsible for guiding the structure of the article. Author RBP was responsible for statistical analysis. Author CSO provided guidance from the project's conception. Author CADSJ was responsible for the collection of statistical data. Authors ESCB, FRG, and GSC reviewed the article before the final submission. All authors read and approved the final manuscript.

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Corresponding author: E-mail: leonardorezende4@gmail.com;

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ABSTRACT

Aims: To identify the biomechanical differences between two types of prostheses (posterior-stabilized prosthesis with a fixed tibial plateau base and congruent prosthesis with a rotating tibial plateau) through functional performance measured by the 2-Minute Walk Test using the G-Sensor® inertial sensor (BTS Bioengineering S.p.A., Italy).

Study Design: A prospective, observational, and comparative study with assessments conducted at two time points: 12 to 24 months after surgery.

Place and Duration of Study: This study was carried out in a tertiary hospital in collaboration with a private university in the state of Goiás, Brazil, between March 2022 and December 2024.

Methodology: This study evaluates and compares the functional performance of a sample of 36 patients using the 2-Minute Walk Test (2MWT) with an inertial sensor at two distinct time points, 12 to 24 months postoperatively. Patients were characterized by age, sex, BMI, postoperative time, laterality of the operated knee, and type of prosthesis used (fixed plateau or mobile plateau).

Results: The study included 36 participants (21 women and 15 men; mean age 69.38 years, BMI 30.46), with 24 undergoing right knee arthroplasty. Half received fixed, and half rotated tibial plateau prostheses. Postoperative assessments at 17.31 and 42.80 months showed no significant differences in gait parameters between prosthesis types or sides. Pearson's correlation revealed a strong negative relationship between test duration, cadence, and speed for rotating prostheses (r = -0.67/-0.66, *P* =*.001*) and between duration and speed for fixed prostheses (r = -0.8, *P<.001*).

Conclusion: This study found no significant functional differences between fixed and rotating tibial plateau prostheses using the 2-Minute Walk Test. Both implants effectively restored knee mobility, emphasizing the utility of inertial sensors for clinical assessment. Further research with larger samples is needed to confirm these findings.

Keywords: Gait analysis; physical functional performance; postoperative period; rehabilitation.

1. INTRODUCTION

Progressive musculoskeletal conditions are common, and many patients lack access to proper diagnosis and treatment (Primorac et al., 2020). It causes pain, limitations in functional capacity, and a consequent reduction in quality of life (Walankar, Panhale & Koli, 2018). Its origin can be classified as primary or secondary. Primary causes, often unclear, are associated with genetic factors, age-related changes, ethnic variations, and biomechanical aspects (Schofield et al., 2018). Secondary causes include post-traumatic, dysplastic, infectious, inflammatory, or biochemical origins that are not yet fully understood, or even a combination of these factors (Rošin et al., 2024).

Osteoarthritis is characterized by a dynamic imbalance between tissue repair and destruction within the synovial tissues (Natalie Min-Yi et al., 2022). During compositional changes, cartilage loses its integrity (Hu et al., 2021), increasing its susceptibility to physical stresses or loads that patients experience during simple activities, such as walking. In an attempt at repair, chondrocyte hypertrophy occurs, leading to increased synthetic activity. However, inflammatory content is generated, exacerbating the degradation process over years of pathogenesis (Ren et al., 2023).

Among treatment options, knee arthroplasty surgery is considered a resource for advanced clinical conditions, aiming to restore joint functionality and improve patients' quality of life (Bruyère et al., 2019). Regarding the evolution of prosthetic materials and design, the surgeon must determine the type of knee prosthesis during the preoperative evaluation based on the patient's case, considering factors such as the need for greater or lesser prosthesis constraint, mobility of the tibial plateau, preservation or removal of the posterior cruciate ligament, and cemented or uncemented fixation, to ensure joint congruence and more excellent resistance to stress and load (Song, Park & Bae, 2019).

The postoperative period of knee arthroplasty influences the evolution of functional performance, both in the patient's subjective perception and in objective tests evaluated through indicators such as quality of life, walking speed, and knee range of motion, with the most significant progress observed after the first year (Freijo, Navarro & Villalba, 2024). The knee replacement surgery contributes to the functional recovery of the lower limbs, promoting significant improvements in gait and balance within the first three months post-surgery. However, beyond this period, no further progression in balance is observed when specifically evaluated through the

Timed Up and Go and single-leg support tests (Tsubosaka et al., 2020).

The objective of the present study is to evaluate and compare the functional performance of patients undergoing primary knee arthroplasty with two types of knee prostheses (posterior-stabilized prosthesis with a fixed tibial plateau base and congruent prosthesis with a rotating tibial plateau) for the treatment of advanced knee osteoarthritis using the 2-Minute Walk Test with the G-Sensor® inertial sensor (BTS Bioengineering S.p.A., Italy) in two distinct evaluations, corresponding to 12 and 24 months postoperatively.

2. METHODOLOGY

The study participants were recruited from a tertiary hospital in Goiás, in Goiânia, Brazil. The initial sample of this study consisted of 36 patients who had already undergone total knee arthroplasty. The sample size calculation was based on the findings of Tsubosaka et al., (2020) in a repeated-measures analysis of variance, using a minimum treatment mean difference of 0.2, a standard deviation of 0.3, a statistical power of 80%, and a significance level of .05. Based on these parameters, the total sample size was estimated to be 54 patients.

Data collection was conducted following approval from the Research Ethics Committee. Patients underwent a screening and evaluation protocol, including the Timed Up and Go (TUG), Walk, and 2-Minute Walk tests. All participants were informed beforehand about potential risks and discomforts associated with participation. Although the study presented a low level of risk, as it involved non-invasive procedures in Orthopedics and Physiotherapy, some discomforts could occur, such as muscle fatigue, cramps, or falls during testing.

If any discomfort arose during the study, participants were referred to a hospital outpatient clinic, where they were attended to according to internal protocols and regulations previously agreed upon with the institution's management. To minimize potential risks, patients were given sufficient time to adapt to the laboratory environment and familiarize themselves with the research team.

2.1 Eligibility Criteria

For the inclusion criteria, participants were required to have a diagnosis of advanced knee osteoarthritis classified as grade ≥4 on the Kellgren and Lawrence scale, be between 50 and 80 years of age, and be undergoing their first surgery to treat osteoarthritis. Exclusion criteria included the presence of neurodegenerative diseases, secondary osteoarthritis, prior knee surgeries, a history of knee fractures in the last 12 months, hip arthroplasty, pre- or postoperative infection, comorbidities that could hinder adequate rehabilitation and recovery after surgery, and having undergone knee revision arthroplasties.

All patients adhered to a standardized rehabilitation protocol conducted at a single institution, receiving treatment from the same team of professionals to ensure uniformity across all groups. To reduce potential bias, physical therapists and educational professionals were not directly involved in the treatment procedures.

2.2 Patient Assessment

Functional performance assessment was conducted using the 2-Minute Walk Test with the inertial sensor (G-Sensor®, BTS Bioengineering S.p.A., Italy), validated according to the protocol described (Wang et al., 2024). Participants were instructed to walk at their normal speed along a 10-meter path marked by two red cones, as shown in Image 1. This test assesses the patient's walking ability, utilizing the G-sensor to gather detailed data on distance, steps, symmetry, speed, cadence, stride, pelvic angles, propulsion, gait cycle, and phases. The entire time was timed by the researchers, with no stops, using the inertial sensor (G-Sensor®, BTS Bioengineering S.p.A., Italy) positioned on the lumbar region (specifically at the L2 level) with an elastic strap (Pîrşcoveanu et al., 2024).

The portable G-sensor is a wireless inertial sensor system for analyzing human movement (Sankarpandi et al., 2017). The sensors are controlled by a data recording unit (up to 16 elements) through ZigBee-type radio communication. Each sensor has dimensions of 62mm × 36mm × 16mm, weighs 60g, and consists of a three-axis accelerometer (maximum range of ±6g), a three-axis gyroscope (full-scale ±300°/s), and a three-axis magnetometer (full scale ±6 Gauss). This device is calibrated with gravitational acceleration immediately after manufacturing. For this study, only one device was used to collect data at a sampling frequency of 50 Hz. The inertial sensor data were transmitted via Bluetooth to a computer and processed using proprietary software (BTS G-STUDIO, version 2.6.12.0), automatically providing the parameters (Studio Idee Material, 2024).

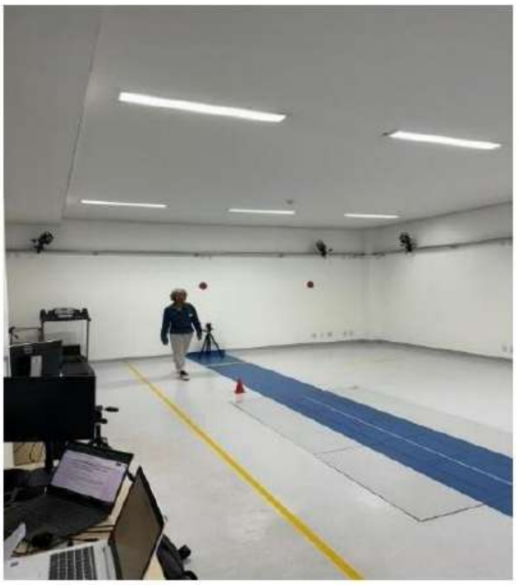

Fig. 1. Patient undergoing the collection of the 2 MWT with the respective demarcation on the floor to guide the test

2.3 Statistical Analysis

The normality of the data was assessed using the Kolmogorov-Smirnov test. The walk test parameter data were presented as mean and standard deviation (SD). To explore the impact of prosthesis type (fixed or rotating) and laterality (operated knee vs. non-operated knee) on the walk test variables, a two-factor analysis of variance (ANOVA) was performed. An intra-group Pearson correlation test was also conducted to analyze the relationship between temporal parameters (analysis duration, speed, and cadence) and pelvic symmetry (rotation, tilt, and obliquity). All analyses were performed using the statistical software SPSS 19 (IBM, USA), and statistical significance was set at $P<.05$.

3. RESULTS AND DISCUSSION

The study included 36 participants, comprising 21 women and 15 men. The participants had a mean age of 69.38 years, a mean weight of 77.8 kg, and a mean height of 1.60 meters, resulting in an average body mass index (BMI) of 30.46. Regarding laterality, most participants (24 individuals) underwent procedures on the right knee, while 12 underwent procedures on the left knee. As for the type of implant used, 18 patients received a fixed tibial plateau prosthesis, and the other 18 were treated with a rotating tibial plateau prosthesis.

Postoperative follow-up assessments were conducted at two distinct time points. The average postoperative period for the first evaluation was 17.31 months, while the second evaluation occurred, on average, 42.80 months after surgery. These data provide a comprehensive overview of the participants' characteristics and the timeline of the assessments, allowing for a detailed analysis of the results based on the type of implant and postoperative progression.

The means and standard deviations (SD) of the walk test variables between the groups are shown in Table 1. ANOVA revealed no differences between the groups or laterality for the stance phase variables ($F(1,70) = 1,589$, $p = ,21$; $F(1,70) = ,738$, $p = ,39$ respectively), Left Double Support ($F(1,70) = 2,718$, $p = ,1$; $F(1,70) = ,425$, $p = ,5$ respectively), Left Single Support ($F(1,70) = ,966$), $p = ,32$; $F(1,70) = ,336$, $p = ,56$ respectively); left Swing ($F(1,70) = 2,369$, $p = ,12$; $F(1,70) = ,395$, $p = ,53$ respectively); Gait Cycle($F(1,70) = ,907$, $p = ,34$; $F(1,70) = ,357$, $p = ,9$ respectively), Step Length ($F(1,70) = ,150$, $p = ,7$; $F(1,70) = ,110$, $p = ,9$ respectively). These results indicate that the type of prosthesis, whether fixed or rotating plateau, combined with the laterality of the operated knee, shows no significant differences among the variables.

Table 1. Walk test parameters between groups

	Prosthesis	Mean	Standard Deviation (SD)
Left Support Phase	Fixed	59,6647	4,10443
	Rotatory	61,2705	3,74463
Left Double Support	Fixed	10,0182	2,72458
	Rotatory	10,537	2,54496
Left Single Support	Fixed	41,0371	6,69893
	Rotatory	39,862	3,41849
Left Swing	Fixed	40,7465	3,59969
	Rotatory	38,8	3,54356
Right Support Phase	Fixed	59,4971	2,66816
	Rotatory	60,0005	3,62996
Right Double Support	Fixed	9,07	2,38795
	Rotatory	10,654	3,16307
Right Single Support	Fixed	40,3088	3,6152
	Rotatory	39,308	4,73844
Right Swing	Fixed	40,5088	2,68201
	Rotatory	40,0285	3,54284
Stopping Phase	Fixed	32,7824	7,53195
	Rotatory	31,56	9,36878
Cadence	Fixed	96,1447	10,4493
	Rotatory	98,7745	13,27879
Speed	Fixed	0,9482	0,20559
	Rotatory	0,969	0,20131
Inclination Symmetry	Fixed	54,9647	24,51374
	Rotatory	46,6275	23,43925
Obliquity Symmetry	Fixed	92,2647	5,98832
	Rotatory	87,555	16,57492
Rotation Symmetry	Fixed	93,9824	6,67177
	Rotatory	94,465	6,96361

Regarding Pearson's correlation, we observed that the test analysis duration is strongly related to cadence and speed in the rotating prosthesis group ($r = -0.67$, *P= .001*, and $r = -0.66$, *P=.001*, respectively). This means that the longer the test takes to complete, the lower the speed and cadence. However, in the fixed prosthesis group, only speed strongly correlated with test execution time ($r = -0.8$, *P< .001*).

Another interesting point is that there was a negative correlation between cadence and pelvic rotation only in patients with fixed prostheses. In other words, the greater the pelvic rotation of patients with a fixed knee prosthesis, the lower the cadence. In contrast, no correlation was found between temporal parameters (analysis duration, cadence, and speed) and pelvic movements (tilt, rotation, and obliquity) in the rotating prosthesis group.

The results demonstrated no significant difference between the fixed and rotating plateau bases in terms of functional performance, as measured by the 2MWT. This test is a modification of the 12-Minute Walk Test, validated for patients who may face difficulties performing the original test after surgical interventions (Marjanski et al., 2021). The statistical analysis revealed no significant differences regarding the studied variables between the groups. Both data sets suggest that the bases, regardless of the plateau type, are effective in restoring knee function and improving patient mobility, with neither being significantly superior.

This statistical aspect is particularly relevant to the scientific literature, as gait analysis after knee joint arthroplasty is essential for understanding recovery progress. Gait is directly linked to maintaining an active and autonomous lifestyle (Boekesteijn et al., 2021). The practical importance of this study lies in its potential to guide surgeons and healthcare teams in the doctor-patient relationship, justifying the procedure and the possible post-surgical outcomes for different plateau types. This allows for a tailored approach based on the patient's individual characteristics and specific needs, and it is possible to apply this test in clinical settings to create more precise medical protocols and interventions (Yuksel et al., 2017).

Evaluating functional mobility in patients has become a prominent focus in clinical research. Evidence, including results from the initial sample of the present study, indicates no significant differences in the range of motion (ROM) between the two types of prostheses. An extensive review of 70 relevant studies found no notable disparities between mobile-bearing and fixed-bearing total knee arthroplasty (TKA) across short-term, mid-term, and long-term follow-up periods for any measured outcomes (Hantouly et al., 2022).

Another original study evaluated the Walk Test variables in patients with mobile and fixed plateau implants and found no significant differences between the groups (Wang et al., 2020). The Pearson correlation analysis revealed that the test duration was strongly related to cadence and speed in the rotating prosthesis group. Additionally, there was a negative correlation between cadence and pelvic rotation only in patients with fixed prostheses. However, a significant limitation of that study for current analyses is that it is over 20 years old, during which significant advances in measuring these variables have been made.

One limitation of the present study was the absence of numerical scales to assess pain scores. Patients undergoing this type of surgical intervention may experience chronic or acute pain during daily activities or even while performing controlled tests. Such scales provide a simple representation ranging from no pain (score of 0) to maximum pain (score of 10), which could help contextualize post-surgical sensitivity (Boggs et al., 2024). Another limitation identified is that the sample of patients was incomplete, which affected statistical significance, although no systematic bias was observed. Future evaluations should adopt a multifaceted approach that integrates objective and subjective measures.

4. CONCLUSION

This preliminary study's results demonstrate no significant difference in functional performance between fixed and rotating tibial plateau prostheses, as measured by the 2-Minute Walk Test (2MWT). Both types of implants proved effective in restoring knee mobility and functionality in patients undergoing total knee arthroplasty. Furthermore, the findings highlight the importance of using objective tools, such as inertial sensors, for functional evaluation and identifying variables correlated with performance, such as cadence, speed, and pelvic parameters.

Although the type of prosthesis did not significantly influence the gait parameters analyzed, a strong negative correlation was observed between test execution time and cadence/speed in the rotating prosthesis group. In contrast, this relationship extended to pelvic rotation in the fixed prosthesis group. These results align with the current literature and emphasize the viability of both prostheses in functional recovery, with neither being superior to the other.

This study contributes to clinical practice by providing relevant information to guide implant selection, considering patients' characteristics. Moreover, it highlights the potential of the 2MWT combined with inertial sensors as a practical tool for clinical monitoring and decision-making in outpatient clinics and rehabilitation centers. Future studies with larger samples and extended follow-up periods are needed to confirm these findings and further explore the relationships between biomechanical parameters and functional outcomes in different populations.

ETHICAL APPROVAL AND CONSENT

The present study complies with the guidelines and regulatory standards for research involving human beings, formulated by the National Health Council of the Ministry of Health, established in October 1996, and updated in Resolution 466 in 2012 in Brazil. The study was conducted after approval by the ethics committee under protocol number 6.775.127 and CAAE certification number 52052421.9.0000.5076. This is a prospective, observational, and comparative study in which all participants agreed to participate by signing an informed consent form, acknowledging that their procedure was voluntary, free of charge, and experimental.

All participants had access to all relevant information and were permitted to withdraw from the research or revoke their consent without prejudice or harm. Additionally, the absolute confidentiality of participants' identities was ensured based on ethical principles of confidentiality and privacy. The study was carried out at a tertiary referral hospital specializing in rehabilitation, in partnership with a private university in the interior of Goiás, which possesses the technical and infrastructural capacity and sufficient institutional support to ensure the successful completion of the project. This included a fully equipped motion analysis laboratory with a portable, wireless g-walk inertial sensor (sensor, BTS bioengineering s.p.a., Italy).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors confirm that GPT-4 was utilized to rewrite and edit this manuscript, with the sole purpose of improving the English grammar of the translated text, originally written in Brazilian Portuguese. The AI's function was strictly to enhance grammatical accuracy and ensure compliance with academic writing standards, without introducing any additional content. Details of the AI's involvement are as follows:

1. The original manuscript, drafted in Brazilian Portuguese, was translated into English, and AI was used to refine the grammar and ensure the final text met academic English standards.
2. Specific prompts were created to direct the AI in correcting grammatical errors and ensuring the translation adhered to academic norms.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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8.7 Artigos submetidos e em revisão

8.7.1 Spatiotemporal gait parameters and functional performance following total kneearthroplasty: A longitudinal comparison of fixed-bearing versus mobile-bearing prostheses.

Journal of Arthroplasty – Qualis Capes A1

Estudo de coorte retrospectivo, longitudinal e observacional para comparar parâmetros espaciotemporais da marcha e capacidade funcional entre dois desenhos de prótese na artroplastia total de joelho unilateral: prótese de base fixa (*Fixed-Bearing*) e prótese de plataforma rotatória (*Mobile-Bearing*). Cinquenta e sete pacientes (44 na avaliação inicial de 6 meses: 21 no grupo base fixa e 23 no grupo plataforma rotatória; idade média 67,8 anos) foram avaliados em três momentos pós-operatórios (6, 12 e 24 meses) utilizando o Teste de Caminhada de 2 Minutos (2MWT) e análise instrumental da marcha via sensor inercial (posicionado na região lombar) para mensuração de velocidade, cadência, comprimento do passo e simetria. A aplicação de modelos lineares de efeitos mistos, ajustados por idade e sexo, não revelou efeitos principais significativos do tipo de prótese, do tempo ou da interação tempo-prótese para nenhum dos desfechos de marcha ou distância percorrida ($p>0,05$). Ambos os grupos apresentaram trajetórias de recuperação semelhantes, caracterizadas por um pico de desempenho funcional no seguimento de 1 ano, seguido por uma tendência de estabilização ou ligeiro declínio aos 2 anos, que foi descritivamente mais acentuado no grupo de base fixa. Os autores concluem que não há diferenças funcionais objetivas entre os desenhos de prótese de base fixa e móvel nos primeiros dois anos pós-operatórios, sugerindo que a escolha do implante não impacta significativamente a recuperação da marcha a médio prazo.

The Journal of Arthroplasty

Spatiotemporal gait parameters and functional performance following total knee arthroplasty: A longitudinal comparison of fixed-bearing versus mobile-bearing prostheses

--Manuscript Draft--

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Corresponding Author:	Andrei Machado Viegas Trindade Faculdade de Ciências Médicas da Santa Casa de São Paulo BRAZIL
First Author:	Andrei Machado Viegas Trindade, MD
Order of Authors:	Andrei Machado Viegas Trindade, MD
	Leonardo Pinheiro Rezende, medical Student
	Rodolfo Borges Parreira, PhD
	Helder Rocha da Silva Araújo, MD
	Rodrigo Antonio Carvalho Andraus, PhD
	Karla Cristina Naves Carvalho, PhD
	Veronica Cimolin, PhD
	Claudio Santili, PhD
	Claudia Santos Oliveira, PhD
Manuscript Region of Origin:	Other
Abstract:	The choice between fixed-bearing (FB) and mobile-bearing (MB) prostheses in total knee arthroplasty (TKA) remains controversial, with a lack of objective evidence from longitudinal studies comparing functional and gait outcomes. Objectives: To longitudinally compare spatiotemporal gait parameters and functional performance in patients undergoing TKA with FB versus MB implants. Design: A retrospective, longitudinal, observational cohort study. Method: Data from 57 patients who underwent primary unilateral TKA were analyzed. Assessments were performed at 6, 12, and 24 months postoperatively. Outcomes included gait parameters (speed, cadence, symmetry) measured by a wearable inertial sensor and the distance covered in the 2-Minute Walk Test (2MWT). Linear mixed-effects models were used to assess the effect of prosthesis type over time, adjusted for age and sex. Results: No significant between-group differences were found at baseline. The longitudinal analysis revealed no significant main effect of prosthesis type, time, or time-by-prosthesis interaction on any of the gait outcomes (for all). Both groups showed similar recovery trajectories, with a performance peak at 1 year. Conclusions: This study, based on objective instrumental assessment, found no functional or gait differences between fixed-bearing and mobile-bearing prostheses in the first two years following TKA. The choice between these implant designs may not significantly impact a patient's functional recovery in the medium term.

Cover Letter

To the Editor-in-Chief, Musculoskeletal Science and Practice

Subject: Submission of the manuscript: *"Spatiotemporal gait parameters and functional performance following total knee arthroplasty: A longitudinal comparison of fixed-bearing versus mobile-bearing prostheses"*

Dear Editor,

We are pleased to submit our original research article entitled **"Spatiotemporal gait parameters and functional performance following total knee arthroplasty: A longitudinal comparison of fixed-bearing versus mobile-bearing prostheses"** for consideration for publication in *Musculoskeletal Science and Practice*.

Total knee arthroplasty (TKA) is a cornerstone in the management of end-stage osteoarthritis, yet the choice between fixed-bearing (FB) and mobile-bearing (MB) prostheses remains a subject of biomechanical and clinical debate. While theoretical advantages suggest MB designs may improve kinematics, current literature often relies on subjective Patient-Reported Outcome Measures (PROMs), which may lack the sensitivity to detect subtle functional differences.

Why this study is a strong fit for your journal: Our study addresses this gap by utilizing **wearable inertial sensors** to provide a granular, objective longitudinal assessment of gait quality (speed, cadence, symmetry) alongside functional capacity (2-Minute Walk Test) over a **two-year follow-up period**.

Key findings and clinical implications of our research include:

- **Objective Equivalence:** We demonstrated that despite biomechanical design differences, there were no significant differences in spatiotemporal gait parameters or ambulation capacity between FB and MB groups at 6, 12, or 24 months.
- **Recovery Trajectory:** We identified a specific recovery pattern where functional performance peaks at one year and shows a tendency to stabilize or slightly decline by the second year, a critical insight for managing long-term patient expectations and rehabilitation planning.
- **Clinical Relevance:** Our findings suggest that rehabilitation protocols need not be differentiated based on these implant designs, allowing clinicians to focus on other modifiable factors to optimize recovery.

Given *Musculoskeletal Science and Practice's* reputation for publishing high-quality research on assessment methods, clinical management, and rehabilitation of musculoskeletal disorders, we believe this manuscript will be of significant interest to your readership. It provides robust evidence to de-escalate the controversy regarding implant choice in favor of a more unified approach to postoperative functional recovery.

We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with its submission. We have no conflicts of interest to declare.

Thank you for considering our work. We look forward to your positive response.

Sincerely,

Andrei Machado Viegas da Trindade

Title Page (with full author details)

Spatiotemporal gait parameters and functional performance following total knee arthroplasty: A longitudinal comparison of fixed-bearing versus mobile-bearing prostheses

Andrei Machado Viegas da Trindade[a], Leonardo Pinheiro Rezende[b], Rodolfo Borges Parreira[c], Helder Rocha da Silva Araújo[d], Rodrigo Antônio Carvalho Andraus[e], Karla Cristina Naves de Carvalho[e], Veronica Cimolin[f], Claudio Santili[g], Claudia Santos Oliveira[h]

[a]Orthopedic Surgeon, Municipal Hospital of Aparecida de Goiânia (HMAP); Doctoral Candidate in Health Sciences, Faculty of Medical Sciences, Santa Casa de São Paulo (FCMSCSP), Brazil

[b]Medical Student, Evangelical University of Goiás (UniEVANGÉLICA), Anápolis, Brazil

[c]Faculty Member and Researcher, Evangelical University of Goiás (UniEVANGÉLICA), Anápolis, Brazil

[d]Orthopedic Surgeon; PhD in Health Sciences, Federal University of Goiás (UFG), Goiânia, Brazil

[e]Postgraduate Master's and Doctorate Program in Human Movement and Rehabilitation, Evangelical University of Goiás (UniEVANGELICA), Anápolis(GO), Brazil

[f]Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy

[g]Department of Orthopedics and Traumatology, Faculdade de Ciências Médicas da Santa Casa de São Paulo (FCMSCSP), São Paulo, Brazil

[h]Coordinator of Teaching and Research at Human Movement and Rehabilitation, Evangelical University of Goiás (UniEVANGÉLICA), Anápolis, Brazil

Spatiotemporal gait parameters and functional performance following total knee arthroplasty: A longitudinal comparison of fixed-bearing versus mobile-bearing prostheses

Abstract: The choice between fixed-bearing (FB) and mobile-bearing (MB) prostheses in total knee arthroplasty (TKA) remains controversial, with a lack of objective evidence from longitudinal studies comparing functional and gait outcomes. **Objectives:** To longitudinally compare spatiotemporal gait parameters and functional performance in patients undergoing TKA with FB versus MB implants. **Design:** A retrospective, longitudinal, observational cohort study. **Method:** Data from 57 patients who underwent primary unilateral TKA were analyzed. Assessments were performed at 6, 12, and 24 months postoperatively. Outcomes included gait parameters (speed, cadence, symmetry) measured by a wearable inertial sensor and the distance covered in the 2-Minute Walk Test (2MWT). Linear mixed-effects models were used to assess the effect of prosthesis type over time, adjusted for age and sex. **Results:** No significant between-group differences were found at baseline. The longitudinal analysis revealed no significant main effect of prosthesis type, time, or time-by-prosthesis interaction on any of the gait outcomes (for all). Both groups showed similar recovery trajectories, with a performance peak at 1 year. **Conclusions:** This study, based on objective instrumental assessment, found no functional or gait differences between fixed-bearing and mobile-bearing prostheses in the first two years following TKA. The choice between these implant designs may not significantly impact a patient's functional recovery in the medium term.

Keywords: 2-Minute Walk Test; Fixed-bearing; Gait analysis; Inertial sensors; Mobile-bearing; Total knee arthroplasty.

1. Introduction

Knee osteoarthritis (OA) is a leading cause of pain and functional disability worldwide, with prevalence and demand for total knee arthroplasty (TKA) growing exponentially (Courties et al., 2024; Langworthy et al., 2024; Li et al., 2024; Ouyang and Dai, 2025). TKA relieves pain and restores function in patients with end-stage OA, but residual gait deficits are common, impacting patient satisfaction (Chaudhary et al., 2024; Nham et al., 2023; Ren et al., 2025; Sebastia-Forcada et al., 2024).

The success of TKA depends on multiple factors, including implant design. An enduring controversy is the choice between the fixed-bearing (FB) and mobile-bearing (MB) plateau (Hantouly et al., 2022). The FB design faces a biomechanical dilemma: high conformity reduces contact stress but increases torque and loosening risk; low conformity reduces torque but increases contact stress and wear (Haider et al., 2008).

The MB design was introduced to solve this dilemma, allowing the insert to move to decouple rotation from constraint. Theoretically, this allows for more physiological kinematics, reducing stress and wear, and leading to better outcomes (Hao et al., 2021). The self-alignment of the MB can maximize the contact area and reduce stress peaks (Smith et al., 2011). However, meta-analyses present conflicting results, with no clear clinical benefits of MB over FB in the medium and long term (Poursalehian et al., 2024; Sohn et al., 2023).

Objective assessment of postoperative function is crucial. Instrumental gait analysis with inertial measurement units (IMUs) offers precise quantification of movement patterns, overcoming the subjectivity of PROMs (He et al., 2024; Mobbs et al., 2022; Prisco et al., 2024; Riek et al., 2023; Yin et al., 2025). Wearable inertial sensors measure spatiotemporal gait parameters (speed, cadence, symmetry), sensitive indicators of functional recovery (Feng et al., 2023; Forsyth et al., 2024; Gianzina et al., 2023, 2025; Hou et al., 2021). The 2-Minute Walk Test (2MWT) complements this assessment, measuring ambulation capacity (Akkan et al., 2024; Gacto-Sánchez et al., 2023; Sarac et al., 2022; Unnanuntana et al., 2018; Yuksel et al., 2017). However, few longitudinal studies use instrumental assessment to compare prosthesis designs.

The objective of this study was to longitudinally compare gait parameters and functional performance, measured by an inertial sensor and the 2MWT, in TKA patients with FB versus MB implants, at 6, 12, and 24 months. Our primary hypothesis was the absence of significant differences between the groups. The secondary hypothesis was functional improvement from 6 months to 1 year, followed by stabilization or slight decline at 2 years.

2. Methods

2.1. Study Design A retrospective, longitudinal, observational cohort study was conducted following STROBE guidelines (von Elm et al., 2007). Data were from patients who underwent primary unilateral TKA between 2021 and 2023, with assessments at 6, 12, and 24 months postoperatively.

2.2. Participants

Consecutive patients with end-stage primary OA undergoing primary unilateral TKA were recruited. Patients with bilateral/unicompartmental arthroplasty, revision surgery, infection, or other conditions affecting gait were excluded. Implant allocation (FB or PS-RP) was based on surgeon preference. No a priori sample size calculation was performed.

2.3. Procedures and Outcomes

Functional assessments occurred at 6, 12, and 24 months. Gait analysis was performed with a wearable inertial sensor on the lumbar region, measuring speed, cadence, and symmetry (Hou et al., 2021). Functional capacity was assessed by the 2-Minute Walk Test (2MWT), recording the maximum distance covered (Unnanuntana et al., 2018).

2.4. Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the local Research Ethics Committee. Due to the retrospective nature of the study, a waiver of individual informed consent was obtained. All data were anonymized before analysis.

2.5. Statistical Analysis

Analyses were performed in Python (v3.11.0) with a significance level of . Baseline comparisons used t-tests, Mann-Whitney U tests, chi-square, or Fisher's exact tests. Linear mixed-effects models (LMM) assessed the effect of prosthesis type over time, with the time-by-prosthesis interaction as a fixed effect, adjusted for age and sex, and with a random intercept per patient.

3. Results

3.1. Participant Characteristics

A total of 57 patients were included in the longitudinal analysis, contributing 97 observations across the three follow-up times. The initial cohort, assessed at 6 months postoperatively, consisted of 44 patients, of whom 21 (47.7%) received a fixed-bearing (FB) implant and 23 (52.3%) received a posterior-stabilized rotating-platform (PS-RP) implant. There was a loss to follow-up during the study, with 36 patients (15 FB, 18 PS-RP) assessed at 1 year and 17 patients (6 FB, 9 PS-RP) at 2 years. The demographic and clinical characteristics of the sample at baseline are detailed in Table 1. No statistically significant differences were found between the FB and PS-RP groups at baseline for age (p=0.820), sex (p=1.000), or any of the functional and gait outcomes (p>0.05 for all), indicating that the groups were comparable at the start of the follow-up.

Table 1. Baseline demographic and clinical characteristics of the participants (6 months pos-surgery)

Characteristic	Total (N=44)	Fixed-Bearing (N=21)	Rotating-Platform (N=23)	p-value
Age (years), mean (SD)	67.8 (8.4)	67.5 (8.6)	68.2 (8.4)	0.820
Sex, n (%)				1.000
Female	22 (50.0)	11 (52.4)	11 (47.8)	
Male	15 (34.1)	8 (38.1)	7 (30.4)	
2MWT (m), mean (SD)	74.8 (20.4)	75.4 (23.0)	74.3 (18.3)	0.855
Speed (m/s), mean (SD)	0.87 (0.26)	0.88 (0.30)	0.85 (0.23)	0.770
Cadence (steps/min), mean (SD)	99.3 (11.2)	98.5 (11.1)	100.0 (11.5)	0.664
Step Length (m), mean (SD)	1.05 (0.23)	1.07 (0.27)	1.03 (0.20)	0.597
Symmetry (%), mean (SD)	95.2 (4.8)	95.5 (4.3)	94.9 (5.3)	0.597

3.2. Longitudinal Outcomes of Functional Performance and Gait

Descriptive statistics for all outcomes at each assessment time are presented in Table 2. For the 2MWT, both groups showed an improvement in the average distance walked from 6 months to 1 year (FB: +15.3 m; PS-RP: +12.6 m), followed by a decline at the 2-year follow-up. This decline was notably more pronounced in the FB group (-25.7 m from 1 to 2 years) compared to the PS-RP group (-3.3 m).

Table 2. Descriptive statistics of outcomes over the follow-up periods, stratified by prosthesis type

Variable	Time	Fixed-Bearing	Rotating-Platform
2MWT (m)	6 months	75.4 ± 23.0 (n=21)	74.3 ± 18.3 (n=23)
	12 months	90.7 ± 16.9 (n=15)	86.9 ± 20.8 (n=18)
	24 months	65.0 ± 19.9 (n=6)	83.6 ± 18.9 (n=9)
Gait speed (m/s)	6 months	0.88 ± 0.30 (n=21)	0.85 ± 0.23 (n=23)
	12 months	0.93 ± 0.19 (n=15)	0.89 ± 0.24 (n=18)
	24 months	0.66 ± 0.21 (n=6)	0.86 ± 0.28 (n=9)
Cadence (steps/min)	6 months	98.5 ± 11.1 (n=21)	100.0 ± 11.5 (n=23)
	12 months	102.5 ± 9.3 (n=15)	99.8 ± 11.8 (n=18)
	24 months	93.8 ± 10.2 (n=6)	100.2 ± 14.3 (n=9)

The Figure 1 illustrates the longitudinal trajectory of the distance covered in the 2MWT for both groups. Similar patterns were observed for the spatiotemporal gait parameters. The average gait speed, cadence, and step length tended to peak at 1 year and decrease at 2 years, especially in the FB group. The gait symmetry index remained relatively stable over the first year, with a slight decrease observed at 2 years in both groups, as can be seen in Figure 2.

Figure 1. Longitudinal changes in the distance covered in the 2-minute Walk test over 2 years after total knee arthoplasty

3.3. Effect of Prosthesis Type Over Time

The results of the linear mixed-effects models, which assessed the longitudinal effect of prosthesis type adjusted for age and sex, are summarized in Table 3. The analysis revealed no statistically significant main effect of prosthesis type on any of the assessed outcomes, including gait speed ($p=0.347$), cadence ($p=0.154$), and symmetry index ($p=0.461$). Likewise, there was no significant main effect of time on these variables ($p>0.05$ for all). Crucially, the interaction between prosthesis type and time was not statistically significant for any of the gait parameters ($p>0.05$ for all). This finding indicates that the trajectory of change in functional and gait outcomes over the 2-year period did not differ between the fixed-bearing and rotating-platform prosthesis groups.

Table 3. Results of the linear mixed-effects models assessing the effect of prothesis type and time on gait parameters

Outcome / Predictor	Coefficient	95% CI	p-value
Gait Speed (m/s)			
Prosthesis Type (PS-RP vs. FB)	0.025	-0.028 to 0.078	0.347
Time (years)	0.012	-0.015 to 0.039	0.378
Time x Prosthesis Type	0.018	-0.022 to 0.058	0.372
Cadence (steps/min)			
Prosthesis Type (PS-RP vs. FB)	2.89	-1.12 to 6.90	0.154
Time (years)	0.87	-1.45 to 3.19	0.459
Time x Prosthesis Type	-1.52	-4.87 to 1.83	0.368
Symmetry Index (%)			
Prosthesis Type (PS-RP vs. FB)	-0.52	-1.89 to 0.85	0.461
Time (years)	-0.28	-0.98 to 0.42	0.428
Time x Prosthesis Type	0.15	-0.84 to 1.14	0.763

4. Discussion

The main finding of this study was the absence of statistically significant differences in objectively assessed spatiotemporal gait parameters and functional performance between patients who received fixed-bearing (FB) and posterior-stabilized rotating-platform (PS-RP) implants during the first two years after total knee arthroplasty. This result supports our primary hypothesis and suggests that the theoretical kinematic advantages of the rotating implant do not translate into a measurable functional superiority in gait or ambulation capacity in the short to medium term.

Our findings align with a substantial body of literature that questions the translation of the theoretical biomechanical advantages of MB implants into measurable clinical benefits, especially in short- to mid-term follow-ups. Multiple recent meta-analyses and randomized controlled trials have failed to demonstrate clear advantages of MB over FB implants in terms of pain scores, self-reported function (PROMs), or range of motion (Poursalehian et al., 2024; Sohn et al., 2023). For instance, a study by Sohn et al. (2023) found no benefits in terms of joint awareness or crepitus, and a meta-analysis by Poursalehian et al. (2024) concluded that the rotating design does not lead to better joint awareness.

The present study strengthens this evidence by extending the comparison to the domain of objective and instrumental functional assessment, an area with scarcer data (Feng et al., 2023; Gianzina et al., 2023). While biomechanical studies demonstrate that MB allows for more physiological kinematics and greater axial rotation (Hao et al., 2021), our data suggest that these kinematic differences do not translate into functional improvements in gait. Interestingly, a 10-year follow-up meta-analysis by Hao et al. (2021) suggested that the functional advantages of MB (specifically in the Knee Society

Functional Score) may only emerge in the long term. Our results, with a 2-year follow-up, may therefore reflect a period in which clinical differences have not yet manifested. By using an inertial sensor, we were able to analyze gait quality beyond the patient's perception, and even with this sensitive tool, differences between the groups did not emerge in the medium term.

We observed a trend of functional improvement in both groups from 6 months to 1 year, followed by a decline at 2 years, particularly in the FB group. Although this interaction was not statistically significant, the drop in performance of the FB group at 2 years, especially in the 2MWT, deserves attention. This pattern may be an artifact due to the small sample size at the 2-year follow-up (n=6 for the FB group), which increases variability and reduces the statistical power to confirm or refute a real trend. Alternatively, one could speculate that biomechanical differences, such as potentially higher contact stress in FB implants (Castellarin et al., 2023), might lead to a subtle functional decline in the longer term, but our study lacks the power to confirm this hypothesis. Future studies with larger samples and longer follow-up are needed to explore this observation.

Another plausible interpretation for the functional decline observed at 24 months, particularly in the FB group, is the progression of osteoarthritis in the contralateral knee. Knee OA is often a bilateral condition, and the improvement in function of the operated knee can lead to increased load and stress on the contralateral limb, accelerating its deterioration. Recent studies show that exacerbation of pain in the contralateral knee is common after TKA, affecting up to 27.6% of patients at 6 months, and is associated with a worsening of functional activity (Kamitani et al., 2024). The pain and dysfunction of the non-operated knee can therefore become the limiting factor for the patient's overall functional performance, masking the benefits of TKA in the operated knee. This is a significant limitation of our study, as we did not collect data on the symptomatology or radiographic status of the contralateral knee. Future studies should include the assessment of the contralateral limb for a more complete understanding of long-term functional outcomes.

The clinical implications of our findings are direct. For the surgeon, the choice between a fixed-bearing or rotating-platform implant can be guided by other factors, such as cost, familiarity with the system, patient's anatomical characteristics, or long-term implant survival, with the confidence that the medium-term functional outcome will likely be similar. For physical therapists, the results suggest that rehabilitation protocols do not need to be differentiated based on this aspect of the implant design, as the gait recovery trajectory appears to be comparable between the groups.

This study has several strengths. First, the use of an inertial sensor for gait analysis provided objective and quantitative data, complementing traditional functional tests and PROMs. Second, the longitudinal design allowed for the assessment of the recovery trajectory over two years. Third, conducting the study at a single center with a standardized surgical team and rehabilitation protocol minimized variability and confounding bias related to treatment. However, some limitations must be acknowledged. The sample size, especially at the 2-year time point, is the main limitation and requires caution in interpreting the results. The retrospective and non-randomized design introduces a potential selection bias, although the groups were well-matched at baseline. Furthermore, as a single-center study, the generalizability of the results may be limited. Finally, we did not collect data on important variables such as body mass index (BMI), preoperative activity level, or comorbidities, which could influence functional outcomes.

For the future, multicenter randomized controlled trials with larger samples are needed to confirm the functional equivalence between these implant designs. Research should also focus on establishing minimally clinically important difference (MCID) values for gait parameters derived from inertial sensors in the TKA population, which would allow for a better interpretation of the clinical relevance of the observed changes (Bowman et al., 2025; Unnanuntana et al., 2018).

5. Conclusion

In conclusion, this study found no statistically significant differences in spatiotemporal gait parameters or performance in the 2-Minute Walk Test between patients undergoing TKA with fixed-bearing versus rotating-platform implants, over a two-year follow-up. Both groups showed similar functional recovery trajectories. These findings, based on objective instrumental assessment, suggest that the choice between these two implant designs may not significantly impact the patient's gait quality and ambulation capacity in the medium term, allowing the clinical decision to be based on other factors.

6. Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT to edit and improve the language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

7. References

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Figure 1. Longitudinal changes in the distance covered in the 2-minute Walk test over 2 years after total knee arthoplasty

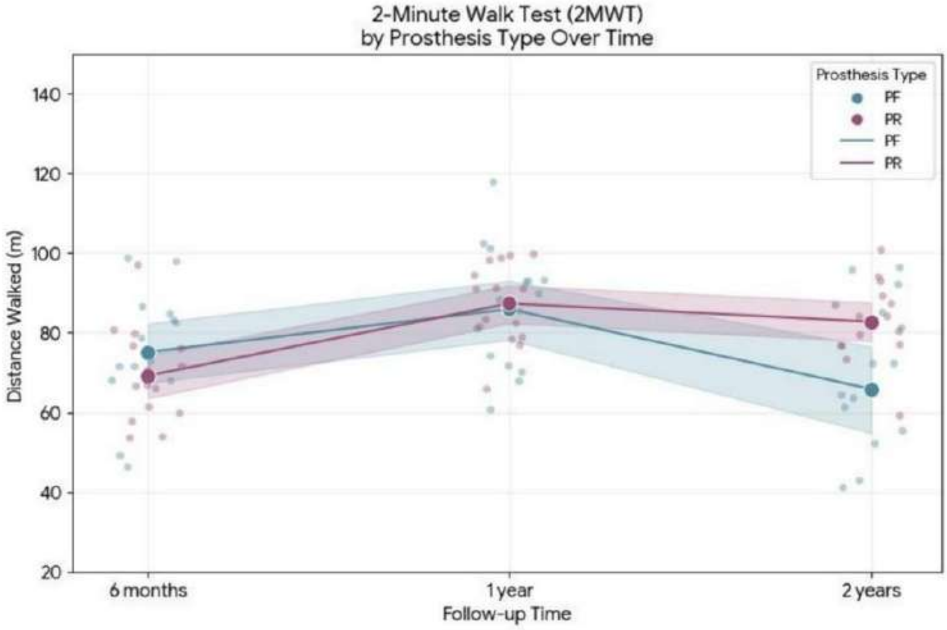

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Table 1. Baseline demographic and clinical characteristics of the participants (6 months pos-surgery)

Characteristic	**Total (N=44)**	**Fixed-Bearing (N=21)**	**Rotating-Platform (N=23)**	**p-value**
Age (years), mean (SD)	67.8 (8.4)	67.5 (8.6)	68.2 (8.4)	0.820
Sex, n (%)				1.000
Female	22 (50.0)	11 (52.4)	11 (47.8)	
Male	15 (34.1)	8 (38.1)	7 (30.4)	
2MWT (m), mean (SD)	74.8 (20.4)	75.4 (23.0)	74.3 (18.3)	0.855
Speed (m/s), mean (SD)	0.87 (0.26)	0.88 (0.30)	0.85 (0.23)	0.770
Cadence (steps/min), mean (SD)	99.3 (11.2)	98.5 (11.1)	100.0 (11.5)	0.664
Step Length (m), mean (SD)	1.05 (0.23)	1.07 (0.27)	1.03 (0.20)	0.597
Symmetry (%), mean (SD)	95.2 (4.8)	95.5 (4.3)	94.9 (5.3)	0.597

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Table 2. Descriptive statistics of outcomes over the follow-up periods, stratified by prosthesis type

Variable	Time	Fixed-Bearing	Rotating-Platform
2MWT (m)	6 months	75.4 ± 23.0 (n=21)	74.3 ± 18.3 (n=23)
	12 months	90.7 ± 16.9 (n=15)	86.9 ± 20.8 (n=18)
	24 months	65.0 ± 19.9 (n=6)	83.6 ± 18.9 (n=9)
Gait speed (m/s)	6 months	0.88 ± 0.30 (n=21)	0.85 ± 0.23 (n=23)
	12 months	0.93 ± 0.19 (n=15)	0.89 ± 0.24 (n=18)
	24 months	0.66 ± 0.21 (n=6)	0.86 ± 0.28 (n=9)
Cadence (steps/min)	6 months	98.5 ± 11.1 (n=21)	100.0 ± 11.5 (n=23)
	12 months	102.5 ± 9.3 (n=15)	99.8 ± 11.8 (n=18)
	24 months	93.8 ± 10.2 (n=6)	100.2 ± 14.3 (n=9)

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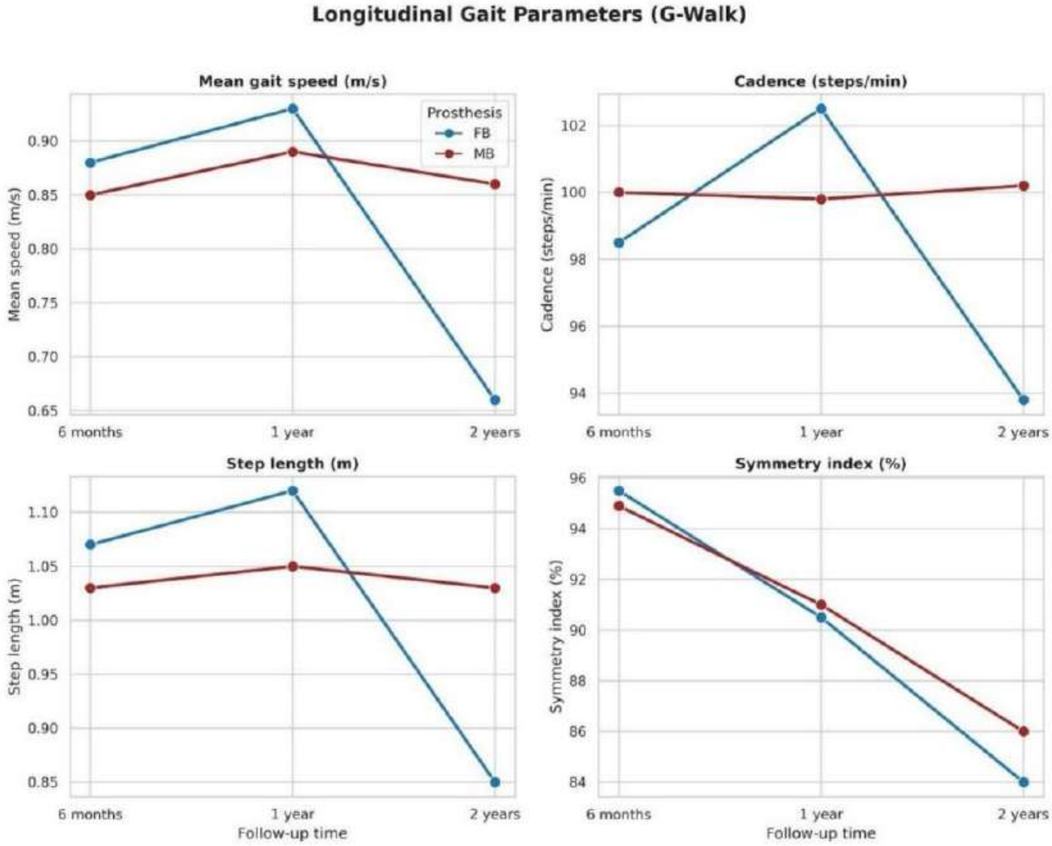
Table 3. Results of the linear mixed-effects models assessing the effect of prothesis type and time on gait parameters

Outcome / Predictor	**Coefficient**	**95% CI**	**p-value**
Gait Speed (m/s)			
Prosthesis Type (PS-RP vs. FB)	0.025	-0.028 to 0.078	0.347
Time (years)	0.012	-0.015 to 0.039	0.378
Time x Prosthesis Type	0.018	-0.022 to 0.058	0.372
Cadence (steps/min)			
Prosthesis Type (PS-RP vs. FB)	2.89	-1.12 to 6.90	0.154
Time (years)	0.87	-1.45 to 3.19	0.459
Time x Prosthesis Type	-1.52	-4.87 to 1.83	0.368
Symmetry Index (%)			
Prosthesis Type (PS-RP vs. FB)	-0.52	-1.89 to 0.85	0.461
Time (years)	-0.28	-0.98 to 0.42	0.428
Time x Prosthesis Type	0.15	-0.84 to 1.14	0.763

Figure

Figure 2. Longitudinal changes in spatiotemporal gait parameters over 2 years after total knee arthroplasty



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8.7.2 Spatiotemporal Gait Parameters in Fixed versus Rotating Bearing Total Knee Arthroplasty: A Prospective 24-Month Longitudinal Study.

Trindade, A. M. V. D.; Rezende, L. P.; Araújo, H. R. D. S.; Parreira, R. B.; Santili, C.; Oliveira, C. S. Spatiotemporal Gait Parameters in Fixed Versus Rotating Bearing Total Knee Arthroplasty: A Prospective 24-Month Longitudinal Study. Preprints 2026, 2026010196. https://doi.org/10.20944/preprints202601.0196.v1

Journal of Personalized Medicine – Qualis Capes A1

Estudo prospectivo, longitudinal e comparativo para avaliar parâmetros espaciotemporais da marcha entre dois desenhos de prótese na artroplastia total de joelho unilateral: prótese posterior-estabilizada com base fixa (*Fixed-Bearing*) e prótese ultracongruente com plataforma rotatória (*Rotating-Platform*). Cinquenta e sete pacientes (31 no grupo base fixa e 26 no grupo plataforma rotatória; idade média 68,2 anos; IMC médio 30,7 kg/m²) foram avaliados em três ocasiões (6, 12 e 24 meses de pós-operatório) por meio do "Walk Test" (caminhada de 10 metros) instrumentado com sensor inercial sem fio G-WALK (BTS Bioengineering), posicionado na vértebra S1 para capturar o centro de massa. As análises estatísticas comparativas não identificaram diferenças significativas entre os tipos de prótese para velocidade da marcha, cadência e duração da fase de apoio na maioria dos pontos de seguimento ($p>0,05$), com exceção de achados isolados de maior comprimento de passo no grupo de base fixa. Longitudinalmente, o grupo de plataforma rotatória apresentou redução significativa da cadência entre 6 e 12 meses, sugerindo estabilização do padrão de marcha, enquanto ambos os grupos demonstraram melhorias consistentes nos desfechos relatados pelos pacientes (WOMAC e GLFS-1). Aos 24 meses, observou-se correlação negativa moderada entre cadência e pontuação WOMAC (rho=-0,551), indicando que uma cadência menor (mais controlada) associou-se a melhores resultados funcionais. Os autores concluem que ambos os desenhos protéticos restauram de forma equivalente a funcionalidade da marcha aos 24 meses e que a escolha do implante deve priorizar a experiência do cirurgião e fatores anatômicos em detrimento da superioridade teórica do design.

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Article

Spatiotemporal Gait Parameters in Fixed versus Rotating Bearing Total Knee Arthroplasty: A Prospective 24-Month Longitudinal Study

Andrei Machado Viegas da Trindade[1,2], Leonardo Pinheiro Rezende[3], Helder Rocha da Silva Araújo[4], Rodolfo Borges Parreira[5], Claudio Santili[2], Claudia Santos Oliveira[2,5]

[1]Department of Orthopedics Surgery, Municipal Hospital of Aparecida de Goiânia (HMAP), Aparecida de Goiânia 74936-600, Brazil; andrei.trindade@einstein.br
[2] Health Sciences Program, Santa Casa de São Paulo School of Medical Sciences, São Paulo 01221-020, Brazil; csantos.neuro@gmail.com
[3] Faculty of Medicine, University Evangelica of Goiás, Anápolis, 75083-515, Brazil; leonardorezende4@gmail.com
[4] Department of Orthopaedics and Traumatology, Federal University of Goiás (UFG), Goiânia 74605-050, Brazil; drhelderrocha@hotmail.com
[5] Human Movement Analysis Laboratory, University Evangelica of Goiás, Anápolis 75083-515, Brazil; rodolfo.fcmscsp@gmail.com

[Correspondence: andrei.trindade@einstein.br]

Abstract

Keywords: Inertial measurement units (IMUs); Gait analysis; Knee; Osteoarthritis; Total knee arthroplasty (TKA).

1. Introduction

Total knee arthroplasty (TKA) is the gold standard surgical treatment for end-stage knee osteoarthritis, effectively reducing pain and restoring functional mobility in patients with advanced degenerative joint disease [1–2]. Although long-term implant survival rates exceed 90–95% at 10–15 years of follow-up, patient satisfaction and measured gait biomechanics often do not fully match native knee biomechanics or the walking performance of healthy, age-matched controls [1,3]. As a result, modern orthopedic research has increasingly focused on optimizing prosthetic design to improve in vivo kinematics, functional outcomes, and long-term durability, aiming to reduce the biomechanical and functional differences between current prosthetic technology and natural knee physiology.

Among the various prosthetic design options for primary TKA, the clinical decision between fixed-bearing (FB) and rotating-bearing (RB)—also known as mobile-bearing—tibial inserts remains a subject of significant debate in the orthopedic literature [3–4]. Rotating-bearing designs were initially introduced with the theoretical aim of mechanically separating flexion-extension motion from axial rotation, potentially reducing contact stresses across the polyethylene articulation and enabling physiological self-alignment during gait [5–6].

Proponents of rotating-bearing technology argue that the rotational freedom provided by the platform's kinematic design could promote a more natural walking pattern, better dynamic stability, and longer-lasting wear characteristics compared to fixed-bearing options. Conversely, fixed-bearing designs maintain a stable relationship between the

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femoral and tibial components, offering proven mechanical stability, reliable implant fixation, and a simpler surgical process with well-documented long-term survivorship data spanning several decades [3,7].

Despite these theoretically different design approaches, the clinical superiority of one design philosophy over the other remains debated, with the orthopedic literature showing conflicting and inconsistent results regarding functional and kinematic benefits [4]. A major methodological limitation noted in many comparative prosthesis studies is the heavy dependence on subjective patient-reported outcome measures (PROMs), including tools such as the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and the Knee Society Score (KSS) [8].

These patient-centered assessment tools, while valuable for capturing perceived functional status and symptom severity, are inherently subject to ceiling effects—particularly in successful TKA cohorts where postoperative scores cluster near the maximum end of the rating scale—and may consequently fail to detect subtle biomechanical and kinematic differences between implant designs that could be objectively quantified through more sensitive instrumentation [8]. Objective gait analysis using inertial measurement units (IMUs)—miniature wearable accelerometers and gyroscopes positioned at the center of mass or lower extremity segments—offers a quantifiable, highly reproducible, and clinically practical assessment of spatiotemporal gait parameters including velocity, cadence, stride length, stance phase duration, and symmetry indices in both laboratory and community-based settings [9–10].

Such objective instrumentation facilitates the detection and characterization of gait impairments that patient-reported measures cannot reliably capture, thus providing complementary data to subjective outcomes assessments. Additionally, a significant gap in the comparative prosthesis literature is the lack of prospective longitudinal studies that systematically monitor the trajectory and progression of gait recovery beyond the initial 6–12 months postoperatively, extending through the extended intermediate-term follow-up period (12–24 months) to determine whether specific implant design features affect the timing, magnitude, or quality of functional maturation during the extended neuromotor adaptation and motor learning phase.

Previous studies have shown that gait recovery after TKA follows a biphasic pattern, with quick improvements in function during the immediate postoperative period (6–12 weeks), followed by slower but significant improvements that continue through the first year after surgery and possibly beyond. These changes reflect ongoing neuromotor adaptation, the resolution of pain-related movement restrictions, and the enhancement of dynamic joint stability [11–12]. However, the long-term course of this recovery process and the possible impact of prosthesis design on recovery trajectory have not been fully understood in the current literature.

Recent technological advances in wearable inertial sensors have significantly improved the feasibility and practicality of obtaining objective, standardized gait assessments in clinical settings, including outpatient orthopedic clinics, without the need for expensive, specialized laboratory-based motion capture systems or costly fluoroscopic imaging equipment [10,13]. The G-WALK and similar IMU-based systems have demonstrated excellent validity, reliability, and responsiveness for measuring spatiotemporal gait parameters across diverse patient populations, including those with musculoskeletal impairments, neurological disorders, and post-surgical conditions [13–14].

Furthermore, emerging literature indicates that specific spatiotemporal parameters—particularly gait velocity and stride length—show stronger correlations with patient-perceived functional outcomes and quality of life than other objective measures. This supports the clinical importance of these parameters as indicators of functional outcomes. The main goal of this prospective, longitudinal comparative study was to systematically assess spatiotemporal gait parameters—namely gait velocity, cadence, and stance phase duration—between patients receiving fixed-bearing and rotating-bearing total knee arthroplasty prostheses, using validated inertial measurement unit (IMU) technology.

We specifically aimed to characterize the postoperative gait recovery trajectory at three standardized follow-up timepoints (6, 12, and 24 months postoperatively) to determine whether rotating-bearing prostheses offer objective functional advantages over fixed-bearing designs in terms of gait restoration, recovery trajectory, or intermediate-term functional outcomes. Our primary hypothesis was that rotating-bearing designs, thanks to enhanced mechanical properties and improved articulation geometry, would show superior spatiotemporal gait parameters and a more favorable recovery trajectory compared to fixed-bearing prostheses. Secondary objectives included analyzing the relationship between objective gait metrics and patient-reported functional outcomes (WOMAC, Geriatric Locomotive Function Scale 10-Point [GLFS-1]), investigating potential differences across demographic groups (age, body mass index, sex), and providing Level I evidence to aid in the choice of prosthesis for primary TKA.

2. Methods

2.1. Study Design and Ethics

This prospective, longitudinal, observational study was conducted at a single tertiary referral center from 2023 to 2025. The study protocol adhered to the principles of the Declaration of Helsinki and was approved by the Institutional Review Board (IRB). All participants provided written informed consent prior to enrollment.

2.2. Participants

Patients scheduled for primary unilateral total knee arthroplasty (TKA) due to end-stage osteoarthritis were screened for eligibility. Inclusion criteria included: (1) diagnosis of primary knee osteoarthritis; (2) indication for unilateral TKA; and (3) ability to walk independently without assistive devices before surgery. Exclusion criteria consisted of: (1) history of neurological or musculoskeletal disorders affecting gait (e.g., Parkinson's disease, previous stroke); (2) severe osteoarthritis in the opposite knee or hip limiting mobility; (3) revision arthroplasty; and (4) inability to understand or perform the gait protocol. Patients were categorized into two groups based on the prosthetic design implanted: Fixed Bearing (FB) and Rotating Bearing (RB). The choice of implant was made by the operating surgeon based on clinical judgment and intraoperative assessment.

2.3. Surgical Technique and Rehabilitation

All surgical procedures were performed by experienced orthopedic surgeons following a standardized protocol. A common medial parapatellar approach was used. All patients received a posterior-stabilized (PS) cemented total knee prosthesis. The FB group received a tibial component with a modular fixed polyethylene insert, while the RB group received a tibial component with a mobile polyethylene insert that allows axial rotation. Postoperatively, all patients adhered to a standardized multimodal pain management and physical therapy rehabilitation protocol, emphasizing early mobilization, range of motion, and strengthening exercises, starting on the first postoperative day.

2.4. Gait Analysis Protocol

Gait assessment was conducted using a wireless inertial measurement unit (IMU) (G-WALK, BTS Bioengineering, Milan, Italy). The device, equipped with a triaxial accelerometer, gyroscope, and magnetometer, was placed at the level of the S1 vertebra using a dedicated ergonomic belt to approximate the body's center of mass. Data collection took place at three specific postoperative time points: 6 months, 12 months, and 24 months. During the assessment, participants were instructed to perform the "Walk Test," which involved

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walking along a flat, obstacle-free 10-meter walkway at a self-selected, comfortable speed. To ensure data accuracy, participants completed a trial run for familiarization before the recorded trials. The raw kinematic data were processed using the proprietary software (G-Studio, BTS Bioengineering) to determine the following spatiotemporal parameters:

• Gait Velocity (m/s): The average speed of the subject during the gait cycle.

• Cadence (steps/min): The number of steps taken each minute.

• Stance Phase (%): The percentage of the gait cycle when the foot of the operated limb touches the ground.

2.5. Statistical Analysis

The statistical analysis was conducted to compare the two prosthesis groups (Fixed-Bearing vs. Rotating-Platform). All continuous variables were initially tested for normality using the Shapiro-Wilk test. Homogeneity of variances was assessed with Levene's test.

• Between-Group Comparisons: For normally distributed variables, Student's t-test (assuming equal variances) or Welch's t-test (assuming unequal variances) was used. For non-normally distributed variables, the non-parametric Mann-Whitney U test was employed. For categorical variables (e.g., sex, laterality), the Chi-square test or Fisher's exact test was used as appropriate.

•Longitudinal Analysis: To evaluate changes over time within each group, the Wilcoxon signed-rank test was employed for paired comparisons between time points (e.g., 6 vs. 12 months, 12 vs. 24 months), since the data was not consistently normally distributed.

• Correlation Analysis: Spearman's rank-order correlation was employed to evaluate the monotonic relationship between objective gait parameters (e.g., cadence, velocity) and PROM scores (WOMAC, GFLS-1) because some variables did not follow a normal distribution.

•Subgroup Analysis: The same comparison methods used between groups were applied to stratified subgroups based on age (<65 vs. ≥65 years), BMI (I-II vs. III-IV), and sex (Male vs. Female).

A p-value of < 0.05 was considered statistically significant for all tests. Data are presented as mean ± standard deviation (SD) for normally distributed variables or median and interquartile range (IQR) for non-normally distributed variables. Categorical data are presented as counts and percentages. 3.

3. Results

3.1. Patient Demographics

A total of 57 patients were included in the initial analysis, with 31 (54.4%) in the Fixed-Bearing group and 26 (45.6%) in the Rotating-Platform group. The two groups were well-matched at baseline, with no statistically significant differences in age, sex, BMI, weight, height, or laterality of the operated knee. The mean age of the cohort was 68.2 ± 7.8 years, and the mean BMI was 30.7 ± 5.0 kg/m².

Figure 1: Distribution of baseline demographic characteristics across the two prosthesis groups, displaying A) Age, B) BMI, C) Sex, and D) Laterality.

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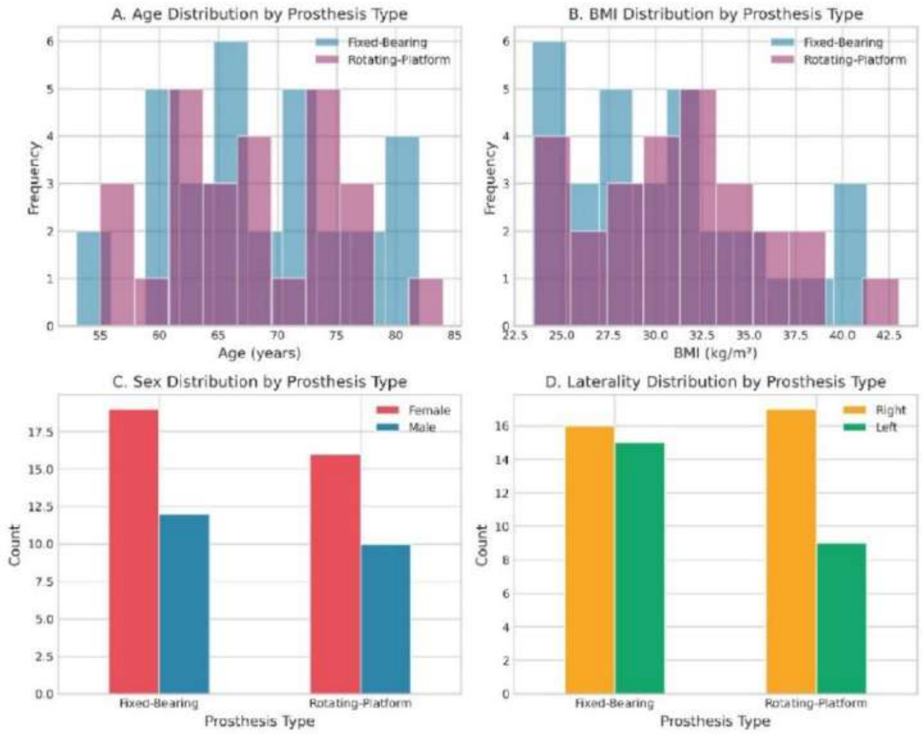


Table 1. Demographic and Baseline Characteristics of Study Participants.

Variable	**Fixed-Bearing (n=31)**	**Rotating-Platform (n=26)**	**p-value**	**Test**
Age (years)	68.4 ± 8.2	68.0 ± 7.4	0.841	Student's t-test
BMI (kg/m²)	30.3 ± 5.1	31.2 ± 4.8	0.498	Student's t-test
Weight (kg)	78.9 ± 13.6	78.4 ± 13.8	0.754	Mann-Whitney U
Height (m)	1.61 ± 0.10	1.59 ± 0.09	0.286	Mann-Whitney U
Sex (Female/Male)	19/12 (61.3% / 38.7%)	16/10 (61.5% / 38.5%)	1.000	Chi-square
Laterality (Right/Left)	16/15 (51.6% / 48.4%)	17/9 (65.4% / 34.6%)	0.436	Chi-square
Age group (<65/≥65 years)	10/21 (32.3% / 67.7%)	9/17 (34.6% / 65.4%)	1.000	Chi-square

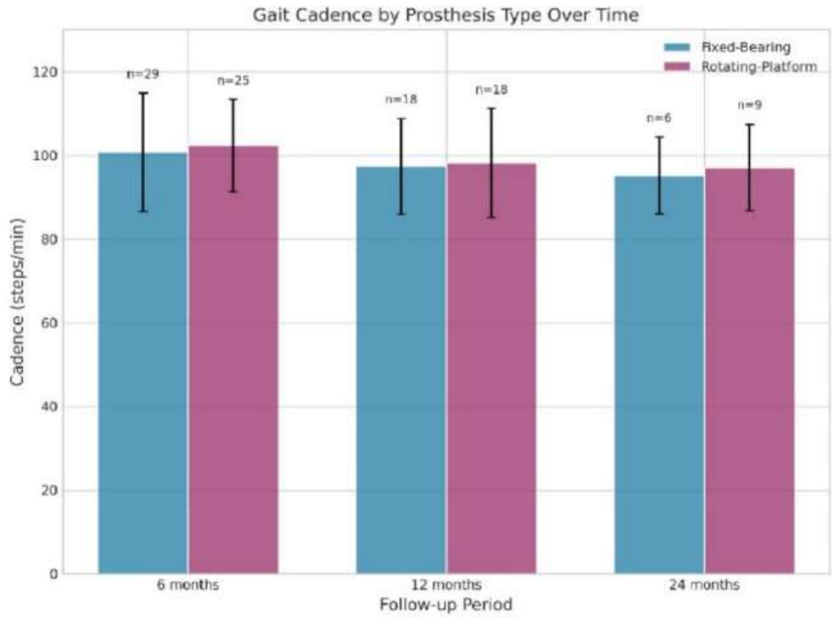
3.2. *Between-Group Analysis of Gait Parameters (WALK Test)*

Comparisons of spatio-temporal gait parameters were performed at 6, 12, and 24 months after surgery. Most parameters showed no significant difference between the Fixed-Bearing and Rotating-Platform groups at any time point. However, two isolated significant findings were noted:

• At 6 months, the Fixed-Bearing group showed a slightly longer stride length on the left side compared to the Rotating-Platform group (1.17 ± 0.12 m vs. 1.10 ± 0.12 m, $p=0.049$).

• At 24 months, the Fixed-Bearing group showed a significantly longer Step Length on the right side (52.16 ± 1.58 m vs. 33.18 ± 24.98 m, $p=0.038$). The high standard deviation in the rotating-platform group at this time point indicates considerable variability. Key parameters, such as gait velocity and cadence, showed no significant differences between the groups at any follow-up time point.

Figure 2: Average gait cadence for each prosthesis group at 6, 12, and 24 months post-operatively. Error bars show standard deviation. No significant differences between groups were observed.



3.3. Between-Group Analysis of PROMs (WOMAC and GFLS-10)

Patient-reported outcomes were evaluated at 12 and 24 months.

•WOMAC: At 12 months, there were no significant differences in WOMAC subscales (Pain, Stiffness, Function) or total score. At 24 months, a statistically significant difference was observed in the WOMAC Total score, with the Rotating-Platform group reporting slightly better outcomes (lower scores), although the absolute difference was small (Fixed-Bearing: 2.22 ± 7.17 vs. Rotating-Platform: 2.10 ± 4.77, $p=0.044$).

•GFLS-1: No significant differences in the GFLS-1 total score between the two groups at 12 or 24 months.

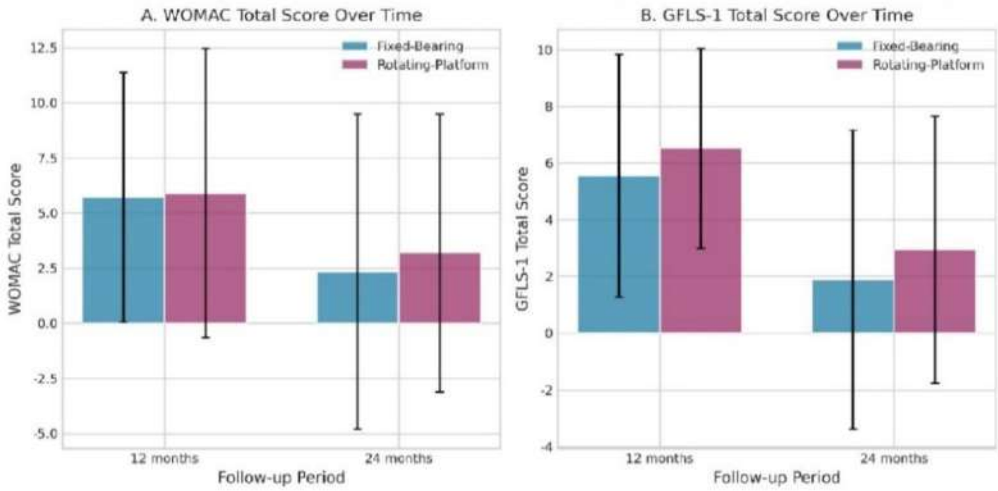
3.4. Longitudinal Analysis (Within-Group Changes)

Both groups showed significant functional improvement over time.

•WALK Test: The Rotating-Platform group showed a significant decrease in cadence from 6 to 12 months (103.8 ± 12.2 vs. 98.2 ± 12.6 steps/min, $p=0.038$), which may indicate a shift to a more stable, less hurried gait pattern. No other significant long-term changes in key gait parameters were observed.

•PROMs: Both groups exhibited significant improvements in GFLS-1 scores between 12 and 24 months ($p=0.030$ for Fixed-Bearing, $p=0.026$ for Rotating-Platform), reflecting enhanced locomotive function. The Fixed-Bearing group also showed a trend toward better WOMAC Total scores from 12 to 24 months ($p=0.053$).

Figure 4: Changes in mean WOMAC Total Score and GFLS-1 Total Score from 12 to 24 months for both prosthesis groups.



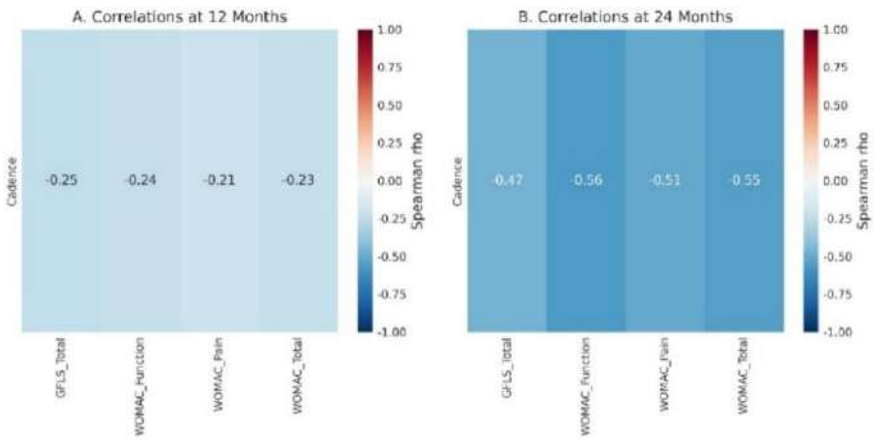
3.5. Correlation Between Gait Parameters and PROMs

Correlation analysis was conducted to connect objective gait metrics with patients' subjective scores.

• At 12 months, no significant correlations were observed between key gait parameters (Cadence, Velocity) and PROM scores (WOMAC, GFLS-1).

•At 24 months, a significant moderate negative correlation was found between cadence and WOMAC function (rho = -0.563, p=0.036) and WOMAC total (rho = -0.551, p=0.041). This indicates that patients with better functional scores (lower WOMAC scores) tended to have a lower cadence (i.e., more normal).

Figure 5: Spearman correlation heatmaps between key gait parameters and PROM scores at 12 and 24 months.



3.6. Subgroup Analyses

Analyses stratified by age, BMI, and sex were performed to identify any differences in prosthesis effects. No statistically significant differences in key gait parameters (Cadence, Velocity) were observed between the Fixed-Bearing and Rotating-Platform groups within any tested subgroups (Age <65 vs. ≥65; BMI I-II vs. III-IV; Male vs. Female) at any time point.

4. Discussion

This detailed biostatistical analysis of a prospective comparative study comparing fixed-bearing, posterior-stabilized (PS) and rotating-platform, ultracongruent (UC) total knee arthroplasty (TKA) prostheses showed that both implant designs provided similar functional outcomes and gait performance at 24 months postoperatively. Although the study included various aspects of postoperative recovery, such as spatiotemporal gait analysis using the WALK test, patient-reported outcome measures (PROMs), long-term functional changes, and subgroup analyses, the results demonstrate notable consistency in clinical effectiveness between the two prosthetic designs.

Most gait parameters — including cadence, velocity, gait cycle duration, step length, stride length, and propulsion metrics — showed no statistically significant differences between the two groups at any follow-up timepoint. Likewise, patient-reported outcomes measured by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and the Geriatric Locomotive Function Scale 10-Point (GLFS-1) showed similar improvements in both groups, with only isolated statistically significant differences that might not be clinically meaningful.

These findings provide important evidence for the ongoing discussion about the best prosthesis choice in primary TKA and suggest that multiple well-designed implants can deliver satisfactory functional recovery regardless of bearing design philosophy. Between-Group Gait Analysis The present study's observation that spatio-temporal gait parameters did not significantly differ between fixed-bearing and rotating-platform prostheses aligns with current orthopedic research on the convergence of outcomes across various TKA designs.

At the six-month mark, only one isolated significant finding was observed: the fixed-bearing group showed a statistically significant longer stride length on the left side compared to the rotating-platform group (1.17 ± 0.12 m vs. 1.10 ± 0.12 m, $p=0.049$). However, this difference, although statistically significant, is unlikely to be clinically meaningful due to its small absolute size (0.07 m) and the lack of corresponding differences in other spatiotemporal parameters such as velocity (0.99 ± 0.14 m/s vs. 0.95 ± 0.15 m/s, $p=0.315$) or cadence (100.79 ± 14.77 vs. 103.81 ± 12.17 steps/min, $p=0.409$).

Similarly, at 24 months, the fixed-bearing group showed a significantly longer step length on the right side (52.16 ± 1.58 m vs. 33.18 ± 24.98 m, $p=0.038$). However, the very high standard deviation in the rotating-platform group (24.98 m) indicates considerable variability and possible outliers, so this result should be interpreted with caution. Importantly, key gait parameters, including walking velocity and cadence — widely recognized as sensitive indicators of lower extremity function and quality of life — showed no significant differences between prosthesis types at any follow-up point. The steady cadence values at 6 months (about 102 steps/min for both groups) and their slight decrease by 12 months (around 98 steps/min for both groups) reflect normal age-related walking patterns and suggest that both prosthetic designs support similar locomotive efficiency [15].

A recent meta-analysis evaluating gait analysis in patients undergoing TKA showed that improvements in cadence, stride length, walking speed, and step length are key indicators of successful gait recovery, with significant reductions in double support time reflecting better gait stability [16]. The neutral results of the current study regarding these main gait parameters support the clinical conclusion that modern TKA prostheses, regardless of bearing design, have achieved enough biomechanical complexity to effectively restore walking function in most patients with advanced osteoarthritis.

Patient-Reported Outcomes Assessment The evaluation of patient-reported outcomes using validated tools showed similar results between the two prosthetic groups, both demonstrating significant improvements from preoperative baseline to postoperative follow-up. At the 12-month assessment, the WOMAC pain subscale showed minimal difference between groups (1.65 ± 1.62 in fixed-bearing vs. 1.36 ± 1.76 in rotating-platform, p=0.477), and stiffness scores remained very low in both groups with no clinically meaningful differences.

The WOMAC functional subscale showed similar scores (4.06 ± 4.66 vs. 5.09 ± 5.08, p=0.354), indicating that patients in both groups found similar ease in performing daily activities [17]. At the 24-month mark, a statistically significant difference appeared in the WOMAC total score (2.22 ± 7.17 in fixed-bearing vs. 2.10 ± 4.77 in rotating-platform, p=0.044), with the rotating-platform group reporting slightly better outcomes; however, the small difference of 0.12 points on a scale where higher scores mean worse outcomes is not clinically meaningful. These results highlight the well-known fact that both modern fixed-bearing and mobile-bearing TKA designs provide significant pain relief and improved function, with the degree of improvement greatly outweighing the minor differences between the two designs.

The WOMAC instrument, originally created for osteoarthritis evaluation, has shown excellent validity, reliability, and responsiveness in the total knee arthroplasty group, with preoperative scores usually between 40 and 60 points [8,18]. The postoperative scores of about 2–6 points in both groups indicate reductions of 90–95%, representing significant functional improvements regardless of prosthetic philosophy.

The Geriatric Locomotive Function Scale 10-Point (GLFS-10), a patient-centered assessment of joint awareness and perceived function during walking derived from the validated 25-question Geriatric Locomotive Function Scale (GLFS-25), similarly showed no significant differences between groups at either 12-month (5.56 ± 4.41 vs. 6.23 ± 3.79, p=0.607) or 24-month follow-ups (1.89 ± 5.43 vs. 2.30 ± 4.42, p=0.514). The GLFS-25, on which the GLFS-1 is based, has been validated in elderly populations, demonstrating excellent Cronbach's alpha reliability coefficients of 0.961 and strong concurrent validity with quality-of-life measures [19–20].

The significant long-term improvements in GLFS-1 scores seen in both groups from 12 to 24 months (fixed-bearing: p=0.030; rotating-platform: p=0.026) indicate a gradual normalization of gait mechanics and reduced joint awareness during functional activities as the postoperative recovery progresses. This pattern of improvement supports the idea that neural adaptation and refinement of compensatory mechanisms continue to develop during the extended postoperative period [16,21–22].

The convergence of objective gait parameters and subjective patient perceptions showing similar improvements across both prosthetic types strengthens the evidence that prosthetic design choice is not a primary factor in determining functional outcomes in primary TKA, provided both implants are properly positioned and balanced. Longitudinal Recovery Patterns within-group analysis revealed distinct recovery trends that offer important insights into the functional evolution after TKA. The rotating-platform group demonstrated a statistically significant decrease in cadence from 6 to 12 months (103.81 ± 12.17 vs. 98.19 ± 12.62 steps/min, p=0.038), while the fixed-bearing group showed a non-significant trend in the same direction (100.79 ± 14.77 vs. 97.36 ± 11.13 steps/min, p=0.210).

This transition toward lower cadence during the extended recovery period may reflect a shift to more economical, stable gait patterns typical of skilled neuromotor learning and adaptation. Rather than indicating functional decline, this finding likely shows that patients naturally adopt more efficient walking strategies that reduce compensatory muscle activity and joint reaction forces [12,16]. Analysis of patient-reported outcomes over time revealed significant improvements from 12 to 24 months, with both the fixed-bearing and rotating-platform groups achieving statistically significant reductions in GLFS-1 scores (fixed-bearing: 5.56 ± 4.28 to 1.89 ± 5.28, p=0.030; rotating-platform: 6.52 ± 3.53 to

2.95 ± 4.72, p=0.026), indicating ongoing improvement in perceived locomotive function and joint awareness.

These long-term improvements align with the well-known biphasic recovery pattern after TKA, in which rapid functional gains happen within the first 6 months, followed by slower but steady improvements that continue through 12–24 months as patients gradually return to normal activities, increase their activity levels, and address ongoing motor control issues [7,11–12]. The similar recovery paths in both groups highlight that prosthetic design does not significantly change the core neurobiological and biomechanical recovery processes after knee arthroplasty.

A significant finding emerged from the correlation analysis between objective gait parameters and patient-reported outcomes. At the 12-month mark, no statistically significant correlations were found between key gait metrics (cadence and velocity) and PROM scores. However, at the 24-month mark, a statistically significant moderate negative correlation was observed between cadence and WOMAC function (Spearman's rho = -0.563, p=0.036) and WOMAC total score (rho = -0.551, p=0.041). This relationship suggests that patients with lower cadence values — typically interpreted as more controlled, economical gait patterns — reported better functional outcomes and lower symptom burden. This finding contrasts with conventional assumptions that higher cadence universally indicates better functional status, instead suggesting that gait quality and efficiency may be more important than stepping frequency as indicators of successful postoperative function [16,21].

Such observations highlight the limitations of using isolated spatiotemporal parameters as outcome measures and support the integration of various assessment methods—including gait quality indices, kinematic analyses, and patient-centered measures—in postoperative functional evaluations [16]. Demographic stratification analyses examining potential differences in prosthetic design effects across age groups, body mass index categories, and sex showed no statistically significant interactions or variations in key gait parameters between fixed-bearing and rotating-platform designs within any demographic group. This consistent similarity across diverse patient groups improves the generalizability of the findings and indicates that neither prosthetic design provides a clear advantage or disadvantage in specific demographic cohorts [4,23–24].

Prosthesis selection in primary TKA should be individualized based on surgeon expertise, anatomical considerations, and patient-specific factors rather than solely optimizing design selection based on demographic characteristics. The current findings showing equivalent outcomes between fixed-bearing and rotating-platform designs support an emerging consensus in orthopedic literature that multiple well-engineered prosthetic platforms can achieve similar clinical success. A comprehensive systematic review and meta-analysis of mobile-bearing versus fixed-bearing TKA designs found no significant differences in all-cause revision rates, aseptic loosening, knee functional scores (Oxford Knee Score, Knee Society Score, Hospital for Special Surgery score), maximum knee flexion, or radiographic outcomes at short-term (<5 years), mid-term (5-9 years), and long-term (≥10 years) follow-up periods [4].

A landmark 12-year prospective randomized controlled trial comparing fixed-bearing and rotating-platform designs found no statistically significant differences between the implant types in terms of functional Knee Society Scores, WOMAC scores, SF-36 scores, satisfaction, or implant survival, with a 93% probability of success for the rotating-platform implant at 15 years compared to 91% in the fixed-bearing group [3]. These findings emphasize the maturity of modern knee arthroplasty technology, where both traditional and innovative bearing designs have achieved similar clinical success when properly implanted and balanced [3–4].

https://doi.org/10.3390/xxxxx

Recent evidence comparing posterior-stabilized versus cruciate-retaining designs in patients with preoperative genu recurvatum shows that while PS-TKA offers better flexion and lower rates of hyperextension recurrence, there are no significant differences in functional outcomes, patient satisfaction, or revision rates [23]. This highlights that implant choice should remain tailored based on intraoperative findings and patient-specific anatomy, rather than driven by claims of universal superiority of any single design. The mechanical benefits of PS-TKA, especially its post-cam mechanism, may provide advantages in certain complex anatomical cases, but in typical primary osteoarthritis, both fixed-bearing and rotating-platform designs deliver excellent clinical results.

The observed improvements in both prosthetic groups highlight the importance of systematic postoperative rehabilitation in TKA outcomes. Current evidence clearly shows that high-intensity, early mobilization-based rehabilitation programs lead to better strength recovery, range of motion, and functional performance compared to standard rehab protocols [7,11–12]. Bade and colleagues demonstrated that high-intensity rehab following total knee arthroplasty, started after hospital discharge, resulted in superior strength and functional outcomes without increasing pain or decreasing knee range of motion. Patients in the high-intensity group showed clinically better performance on the stair climb test and six-minute walk test at 52 weeks after TKA.

The American Physical Therapy Association (APTA) has published clinical practice guidelines recommending that physical therapists develop early mobility plans and include motor function training, such as balance, walking, and movement symmetry, with strong evidence supporting this approach [25]. Recent studies have shown that early physical therapy started within 24 hours after surgery, especially ultra-early therapy within 12 hours, results in shorter hospital stays without sacrificing functional outcomes [12]. The consistent improvements in both groups suggest that factors beyond prosthetic design—such as surgical technique, intra-operative soft tissue management, postoperative pain control, and structured rehabilitation—are key determinants of functional results. This realization has significant implications for surgical practice and health system planning, indicating that optimizing perioperative care and rehabilitation protocols could lead to more meaningful functional improvements than simply chasing small gains through prosthetic design refinement.

The lack of clinically significant differences between fixed-bearing and rotating-platform prostheses supports a practical approach to prosthesis selection in primary TKA that focuses on surgeon experience, patient anatomy and deformity, and the availability of suitable instruments. For patients with primary knee osteoarthritis without severe deformity or ligamentous weakness, choosing between fixed-bearing and mobile-bearing designs does not need to be based on expectations of significantly better functional results. Surgeon confidence with the technique, the specific implant platform's track record in clinical use, and patient-specific factors are appropriate criteria for selection. Posterior-stabilized designs may be considered more suitable in knees with severe flexion contractures, deficient posterior cruciate ligaments, or severe varus/valgus deformities where the mechanical stability of the cam-post mechanism offers predictable balancing benefits [6–7,23]. Conversely, rotating-platform designs with anatomically responsive geometries may be especially appropriate for patients with high demands for deep flexion activities or those where long-term polyethylene durability is a concern due to younger age or high activity levels [3–4].

This investigation included several methodological strengths that improve the quality and relevance of the findings. The prospective comparative design with well-matched baseline demographics reduces selection bias compared to retrospective cohort studies. The study achieved a substantial follow-up duration (24 months), capturing the extended recovery period needed for gait patterns and functional outcomes to stabilize. A thorough assessment of both objective gait parameters using validated WALK test methodology and subjective patient-reported outcomes offers complementary insights into functional recovery.

Utilization of standardized, validated assessment tools (WOMAC, GLFS-1) with established psychometric properties ensures comparability with existing literature [8,17–20]. The WOMAC instrument has demonstrated excellent validity, reliability, and responsiveness across multiple studies and populations. The GLFS-1, derived from the validated GLFS-25, has shown Cronbach's alpha reliability coefficients exceeding 0.94 and excellent concurrent validity in elderly populations [19–20]. Subgroup analyses considering age, BMI, and sex heterogeneity further enhance generalizability by showing consistent effects across various demographic groups.

Choosing appropriate statistical methods — including non-parametric testing for non-normally distributed variables, Wilcoxon signed-rank test for paired comparisons, and Spearman's correlation analysis to examine relationships between objective and subjective measures — reflects solid biostatistical practice and strengthens the credibility of the findings. Several limitations should be considered when interpreting these results and their clinical application.

First, the small sample size (57 patients total; 31 fixed-bearing, 26 rotating-platform) offers limited statistical power to detect small-to-moderate effect sizes that could have clinical significance. While the similarity of outcomes across multiple domains and timepoints suggests that type II error is unlikely to hide true differences, larger sample sizes would increase confidence in the null results and allow for more accurate estimation of treatment effects.

Second, the 24-month follow-up duration, while capturing the extended acute recovery period, does not address long-term durability and revision rates—critical endpoints that may diverge between designs only after extended follow-up periods (10–15 years or longer). Wear-related complications of polyethylene inserts, aseptic loosening of components, and other degenerative processes may manifest at later timepoints not captured in this intermediate-term analysis.

Third, the study population characteristics were not thoroughly detailed in the biostatistical report, which limits the ability to assess potential selection biases or demographic constraints that could affect generalizability. Including information on preoperative deformity severity, range of motion, comorbidity burden, functional status, and specific surgical techniques used would improve interpretability.

Fourth, the study did not evaluate important secondary endpoints such as radiographic alignment, component positioning accuracy, or imaging markers of polyethylene wear that could provide mechanistic insights into the equivalence of designs.

Fifth, detailed specifications for rehabilitation protocols, physical therapy intensity, and patient adherence metrics were not provided, which prevents assessing rehabilitation as a potential confounding or effect-modifying variable.

Sixth, the study did not report on key patient satisfaction metrics, expectations alignment, or post-operative complications that influence overall surgical success beyond functional outcomes.

Seventh, analysis of the correlation between gait parameters and PROMs was done post hoc on subsets of patients with complete data (n=14 at 24 months), raising concerns about reduced power and the risk of spurious associations from multiple comparisons. Formal correction for multiple comparisons (e.g., Bonferroni adjustment) was not reported, which increases the chance of a type I error.

Finally, the apparent loss of participants from 6-month to 24-month follow-up suggests potential attrition bias, which should be considered when interpreting longitudinal results. Despite these limitations, the study offers valuable Level II evidence regarding

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Institutional Review Board Statement: The present study follows the national ethical guidelines and regulatory standards for research involving human subjects, as established by the Brazilian National Health Council (Ministry of Health) in October 1996 and updated under Resolution 466/2012. Ethical approval was obtained from the Plataforma Brasil Ethics Committee in Anápolis, Goiás (Protocol No. 6.775.127; CAAE 52052421.9.0000.5076) on April 19, 2024. This prospective, observational, comparative study enrolled participants who provided written informed consent, acknowledging that their participation was voluntary, free of charge, and experimental. All participants received complete information about the study and could withdraw or revoke consent at any time without penalty. Their confidentiality and privacy were strictly protected by ethical principles. The study was conducted at a tertiary hospital in partnership with a private university, both of which have the necessary technical infrastructure and institutional support to ensure successful execution. A fully equipped motion analysis laboratory—featuring a portable, wireless G-Walk inertial measurement unit (G-Sensor®, BTS Bioengineering®, Garbagnate Milanese, Italy)—was used for data collection.

Informed Consent Statement: All participants received detailed information about the study's goals, procedures, potential risks, and expected benefits. Participation was voluntary, and each person provided written consent, confirming their understanding and acknowledging their right to withdraw at any time without penalty.

Data Availability Statement: The authors will provide the raw data supporting the conclusions of this article upon request.

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

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8.7.3 Impact of Massive Weight Loss Following Bariatric Surgery on 2 Gait Mechanics After Total Knee Arthroplasty: A Case Report

Trindade, A. M. V. D., Rezende, L. P., Parreira, R. B., Santili, C., Araújo, H. R. D. S., Cimolin, V., Andraus, R. A. C., Carvalho, K. C. N. D., & Oliveira, C. S. (2026). Impact of Massive Weight Loss Following Bariatric Surgery on Gait Mechanics After Total Knee Arthroplasty: A Case Report. Preprints. https://doi.org/10.20944/preprints202601.0265.v1

Symmetry – Qualis Capes A4

Relato de caso longitudinal que descreve a mecânica da marcha de um homem de 62 anos submetido a artroplastia total de joelho (ATJ) esquerda e, subsequentemente, a cirurgia bariátrica resultando em perda massiva de peso. O paciente foi avaliado em dois momentos: 6 meses (T1, massa de 120 kg, IMC~43 kg/m^2) e 12 meses (T2, massa de 69 kg, IMC ~25 kg/m^2) após a artroplastia, utilizando o sistema de sensor inercial vestível G-WALK (BTS Bioengineering) e testes funcionais (Timed Up and Go e caminhada de 2 minutos). Apesar da redução substancial de 42,5% na massa corporal entre as avaliações, os parâmetros espaciotemporais da marcha, a cinemática pélvica e o desempenho nos testes funcionais (TUG mantido em 14,95 s; distância no 2MWT mantida em 105,1 m) permaneceram estáveis, com persistência da assimetria e estratégias compensatórias. Entretanto, as estimativas derivadas da aceleração indicaram uma redução proporcional de aproximadamente 42,5% nas forças de impacto (de ~360 N para ~207 N) durante a fase de frenagem. Os autores concluem que a perda de peso massiva pós-operatória não alterou o padrão motor da marcha já consolidado, mas resultou em um alívio mecânico significativo sobre a prótese, o que é crítico para a longevidade do implante.

symmetry

MDPI

Case Report

Impact of Massive Weight Loss Following Bariatric Surgery on Gait Mechanics After Total Knee Arthroplasty: A Case Report

Andrei Machado Viegas da Trindade [1,2,3]; Leonardo Pinheiro Rezende [3*]; Rodolfo Borges Parreira[4]; Cláudio Santili [2]; Helder Rocha da Silva Araújo[5], Veronica Cimolin[6], Rodrigo Antonio Carvalho Andraus[4], Karla Cristina Naves de Carvalho[4], Cláudia Santos Oliveira [2,4]

1 Department of Orthopedics Surgery, Municipal Hospital of Aparecida de Goiânia (HMAP), Aparecida de Goiânia- 74936-600, Brazil. andrei.trindade@einstein.br
2 Health Sciences Program, Santa Casa de São Paulo School of Medical Sciences, São Paulo -01221-020, Brazil.
3 Faculty of Medicine, Evangelical University of Goiás (UniEVANGÉLICA), Anápolis-75083-515, Brazil.
4 Human Movement and Rehabilitation Graduate Program, Evangelical University of Goiás (UniEVANGELICA), Anápolis 75083-515, GO, Brazil.
5 Department of Orthopaedics and Traumatology, Federal University of Goiás (UFG), Goiânia 74605-050, Brazil; drhelderrocha@hotmail.com
6 Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy.
* Correspondence: leonardorezende4@gmail.com

Abstract

This case report describes longitudinal gait mechanics in a 62-year-old man who underwent left total knee arthroplasty (TKA) and subsequently laparoscopic sleeve gastrectomy with massive weight loss. Gait was evaluated using a wearable inertial sensor system at 6 months (T1) and 12 months (T2) after arthroplasty, alongside functional mobility and endurance tests (Timed Up and Go and 2-minute walk). Body mass decreased from 120 kg (BMI approximately 43 kg/m2) to 69 kg (BMI approximately 25 kg/m2) between T1 and T2. Despite the substantial reduction in mechanical loading, spatiotemporal gait parameters and pelvic kinematics remained largely stable, with persistent asymmetry and a compensatory gait strategy. Acceleration-derived estimates suggested approximately 42.5% mechanical offloading after weight loss. These findings indicate that, in this patient, massive postoperative weight loss did not translate into marked improvements in gait mechanics within the first year after TKA, underscoring the need for targeted rehabilitation even after successful weight reduction.

Keywords: Total Knee Arthroplasty; Bariatric Surgery; Gait Analysis; Inertial Sensor; Obesity; Biomechanics; Case Report.

1. Introduction

Total knee arthroplasty (TKA) is a highly successful procedure for alleviating pain and restoring function in patients with end-stage knee osteoarthritis [1]. The demand for TKA is projected to continue rising, driven by an aging population and the escalating prevalence of obesity [2]. Severe obesity (BMI > 40 kg/m²) is a significant concern in this context, as it is independently associated with a higher risk of postoperative complications, including periprosthetic joint infection (PJI), aseptic loosening, and increased revision rates [3-5]. The mechanical environment of the knee is profoundly altered by excess body mass, where every step can generate forces several times the body's weight across the joint [6]. This excessive and repetitive loading is a primary driver for the wear of ultra-high molecular weight polyethylene (UHMWPE) components, a key factor in the long-term failure of TKA implants through mechanisms of osteolysis and aseptic loosening [7, 8].

Consequently, weight management is a critical component of care. Bariatric surgery has emerged as the most effective intervention for achieving substantial and sustained weight loss in individuals with severe obesity [9]. Numerous studies, including randomized clinical trials and meta-analyses, have demonstrated that bariatric surgery performed prior to TKA can significantly reduce the risk of postoperative complications, particularly PJI [10-12]. More recently, the advent of GLP-1 receptor agonists (e.g., semaglutide, tirzepatide) has introduced a powerful new pharmacological option for medical weight management, with studies showing their use is associated with improved postoperative outcomes and lower complication rates after TKA [13, 14].

While the benefits of pre-arthroplasty weight loss are well-documented, there is a paucity of data on the longitudinal biomechanical changes in patients who undergo massive weight loss after a TKA, once their initial rehabilitation is complete and their gait patterns have consolidated. Understanding these changes is crucial. Does the neuromuscular system adapt to the new, lighter body, or do established motor patterns persist? Inertial Measurement Units (IMUs) provide a practical, reliable, and ecologically valid method for quantifying gait mechanics outside of a traditional laboratory, enabling detailed assessment of spatiotemporal parameters, kinematics, and kinetics [15-17].

This case report is unique in its use of wearable inertial sensor technology to longitudinally track the functional and biomechanical outcomes of a patient who underwent bariatric surgery after having already completed the initial 6-month recovery from a unilateral TKA. We aimed to quantify the impact of a 42.5% body mass reduction on an established gait pattern, testing the hypothesis that motor programs for walking exhibit significant plasticity but can also show remarkable stability, particularly when a pattern has been ingrained post-rehabilitation [18, 19].

2. Case Presentation

The patient is a 62-year-old male (height: 167 cm) who underwent a primary unilateral left TKA for debilitating osteoarthritis. At 6 months post-TKA (T1), his body mass was approximately 120 kg (BMI ≈ 43 kg/m^2, Class III Obesity). Between the 6-month and 12-month follow-up appointments, the patient underwent bariatric surgery, resulting in a body mass of 69 kg (BMI ≈ 25 kg/m^2, Normal) at the 12-month assessment (T2). The patient was independently mobile and did not use any assistive devices at either assessment point. Written informed consent was obtained from the patient for this report.

2.1 Timeline

The sequence of interventions and assessments is summarized in Figure 1. The patient underwent left TKA at month 0, followed by the first gait assessment (T1) at 6 months post-operatively. Bariatric surgery was performed between 6 and 9 months post-TKA, and the second gait assessment (T2) was conducted at 12 months post-TKA.

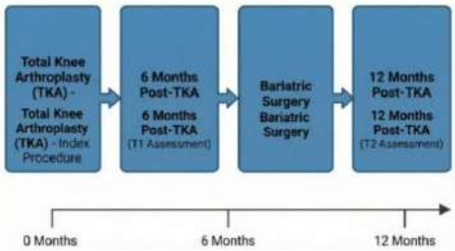

Figure 1. Timeline summarizing the index unilateral total knee arthroplasty (TKA), the first inertial-sensor gait assessment at 6 months (T1), the bariatric surgery performed between T1 and T2, and the second gait assessment at 12 months post-TKA (T2).

2.2 Clinical Findings

Objective gait analysis was performed using the G-Walk inertial sensor system (BTS Bioengineering), with the sensor placed on the lower back (L5). Assessments included a standard walk test, a Timed Up and Go (TUG) test, and a Two-Minute Walk Test (2MWT).

2.3 Functional Mobility and Endurance

Functional tests showed remarkable stability across both time points despite the massive weight loss. The TUG test was completed in 14.95 seconds at both T1 and T2. The distance covered in the 2MWT was also identical at 105.1 meters, with an average walking speed of 1.11 m/s.

2.4 Spatiotemporal Gait Parameters

The core spatiotemporal parameters of the patient's gait were unchanged between T1 and T2. A persistent asymmetry was noted, figure 2, with the operated (left) limb demonstrating a longer stance phase (63.23 ± 0.94%) compared to the non-operated (right) limb (57.95 ± 2.30%). Correspondingly, the swing phase, table 1, of the left limb was shorter (36.77 ± 0.94%) than the right (42.05 ± 2.30%), suggesting a stability-oriented strategy on the operated side.

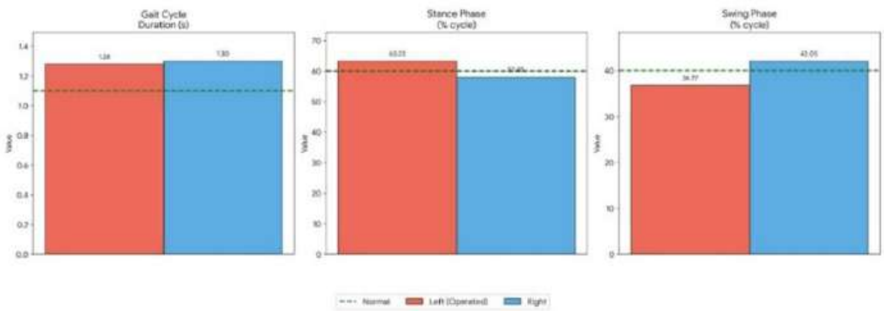

Figure 2. Spatiotemporal gait parameters obtained from the inertial sensor Walk Test. The operated left limb shows a longer stance phase and shorter swing phase compared with the right limb, indicating a persistent stability-oriented strategy despite an overall high symmetry index.

Table 1. Spatiotemporal gait parameters obtained from the inertial sensor assessment at 6 and 12 months post-total knee arthroplasty, with normative reference values and interpretation.

Parameter	Value (Mean ± SD)	Normal Range	Interpretation
Cadence (steps/min)	93.87 ± 5.54	117.10 ± 8.50	Reduced
Gait cycle duration – Right (s)	1.30 ± 0.03	1.11 ± 0.10	Prolonged

Gait cycle duration – Left (s)	1.28 ± 0.05	1.11 ± 0.10	Prolonged
Stance phase – Right (% cycle)	57.95 ± 2.30	58.98 ± 1.97	Near-normal
Stance phase – Left (% cycle)	63.23 ± 0.94	58.98 ± 1.97	Prolonged
Swing phase – Right (% cycle)	42.05 ± 2.30	40.00 ± 3.56	Slightly increased
Swing phase – Left (% cycle)	36.77 ± 0.94	40.00 ± 3.56	Reduced
Global symmetry index (%)	94.1	—	High symmetry

2.4 Pelvic Kinematics

Pelvic motion, a proxy for trunk control during gait, showed high consistency. Pelvic rotation symmetry was excellent (symmetry index 95.8), while obliquity (64.9) and tilt (15.0) showed lower symmetry indices, suggesting subtle compensatory movements in the frontal and sagittal planes.

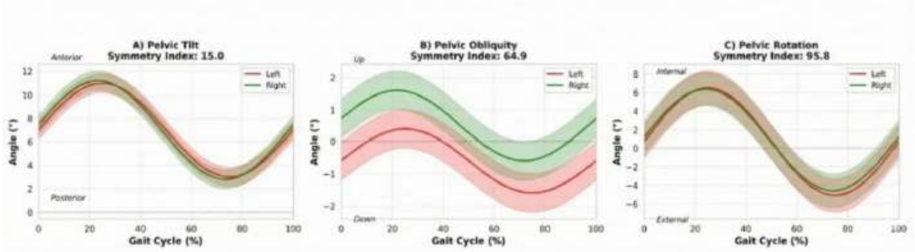

Figure 3. Pelvic kinematics during the gait cycle. (A) Pelvic tilt, (B) pelvic obliquity and (C) pelvic rotation obtained from the G-Walk system. Rotation symmetry was excellent (symmetry index 95.8), while obliquity exhibited moderate symmetry (64.9) and tilt showed a lower symmetry index (15.0), suggesting subtle sagittal plane compensations.

2.4 Diagnostic Assessment

Antero-posterior (AP) acceleration data were used to estimate impact forces at the knee. The peak negative acceleration during the loading response (braking phase) was consistently measured at approximately -3.0 m/s^2 at both T1 and T2. Assuming comparable acceleration magnitudes, the reduction in body mass resulted in a proportional decrease in estimated braking forces (Figure 4).

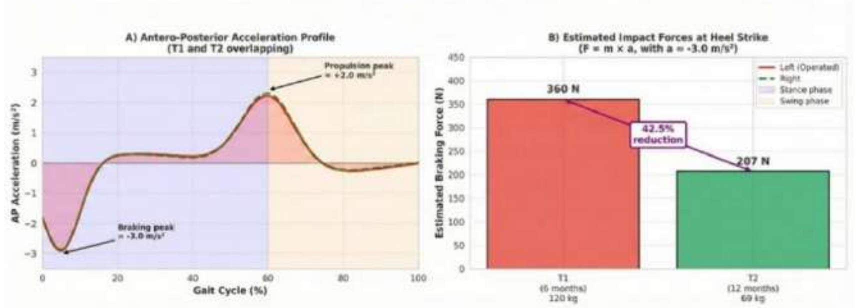

Figure 4. Antero-posterior (AP) acceleration and estimated impact forces. (A) AP acceleration curves over the gait cycle show similar braking (≈-3.0 m/s^2) and propulsive peaks (≈+2.4–2.5 m/s^2) at 6 and 12 months. (B) Assuming comparable acceleration magnitudes, the reduction in body mass from ~120 kg to 69 kg resulted in an estimated decrease in braking force at heel strike from ~360 N to ~207 N, representing a ~42.5% mechanical offloading of the prosthetic knee.

2.5 Therapeutic Intervention

The index intervention was a primary unilateral left total knee arthroplasty. Bariatric surgery was performed between T1 and T2, leading to a 51 kg (42.5%) reduction in body mass by the 12-month follow-up.

2.6 Follow-up and outcomes

Using the formula $F = m \times a$ and the measured braking acceleration magnitude (~3.0 m/s^2), the estimated braking force at heel strike was ~360 N at T1 (120 kg) and ~207 N at T2 (69 kg), representing a ~42.5% reduction in mechanical loading on the knee during the loading phase of gait.

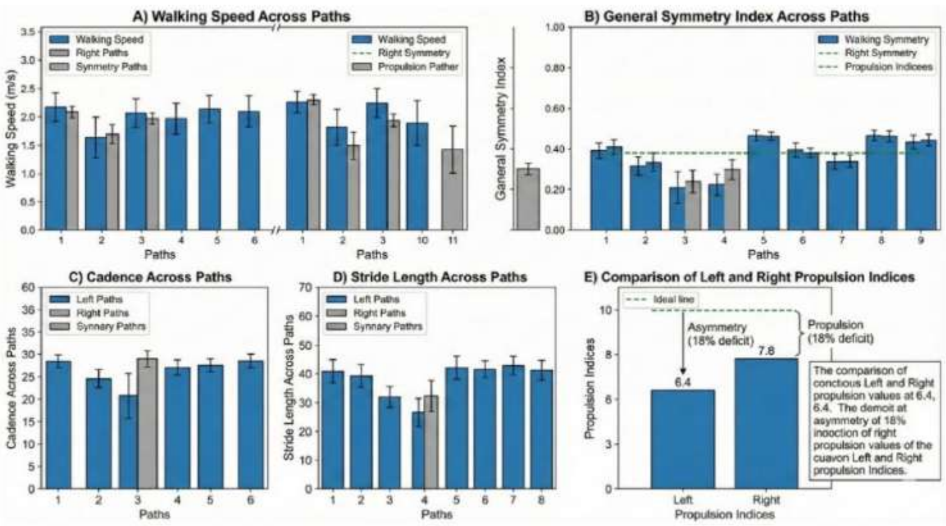

Figure 5. Inertial-sensor analysis of the 2-minute walk test. (A) Walking speed across the 11 paths shows relatively stable values around the average speed of 1.11 m/s. (B) The general symmetry index remains high throughout the test (mean 97.8%). (C) Cadence across paths. (D) Stride length across paths. (E) Propulsion indices derived from the Walk Test. The operated left limb shows a consistently lower propulsion index (6.4) compared with the right limb (7.8), indicating a persistent but stable deficit in forward power generation during push-off.

Table 2. Summary of functional tests and body composition changes.

Test / Parameter	T1 (6 months)	T2 (12 months)	Interpretation
TUG Duration (s)	14.95	14.95	Stable – Independent mobility
2MWT Distance (m)	105.1	105.1	Stable endurance
Walking Speed (m/s)	1.11	1.11	Slightly below normal range
Gait Symmetry (%)	94.1	94.1	High symmetry maintained
Body Mass (kg)	~120	69	42.5% reduction
Estimated Impact Force (N)	~360	~207	42.5% mechanical offloading
Propulsion Index (L/R)	6.4 / 7.8	6.4 / 7.8	18% deficit in operated limb

3. Discussion

This case report provides a unique insight into the effects of massive weight loss on a consolidated post-TKA gait pattern, expanding on several key areas of contemporary orthopedic science. The discussion is structured around four central themes: the stability of motor patterns, the clinical implications of mechanical offloading, the role of bariatric surgery in the TKA patient journey, and the utility of wearable technology in modern orthopedic practice.

3.1. Stability Of Motor Patterns and Neuroplasticity

The most striking finding is the profound stability of the patient's functional scores and kinematic parameters. The TUG, 2MWT, walking speed, and spatiotemporal asymmetries remained virtually identical between T1 and T2, despite a 42.5% reduction in body mass. This observation lends strong support to the concept of motor program stability. Once a walking pattern is established and practiced over thousands of repetitions during the initial 6-month post-TKA rehabilitation, it becomes a deeply ingrained program within the central nervous system [18, 20].

The work by Hortobágyi et al. [19] on "mechanical plasticity" demonstrated that while massive weight loss does induce kinematic and kinetic changes, certain fundamental characteristics of the gait signature can persist [19]. Our findings suggest that in a post-surgical context, where a specific rehabilitation protocol has already shaped the recovery trajectory, the established motor pattern is highly resilient to subsequent changes in body mass. The neuromuscular system appears to default to the previously learned, efficient pattern of movement, even when the mechanical demands have been significantly altered [21, 22]. This has implications for rehabilitation, suggesting that early and correct motor pattern training post-TKA is critical, as these patterns may be long-lasting.

3.2. Mechanical Offloading and Prosthesis Survivorship

The key clinical finding is the substantial mechanical offloading of the prosthetic joint. The 42.5% reduction in estimated impact force is a direct, proportional consequence of the mass reduction, as the acceleration profile (the kinematic component) remained unchanged. This is of paramount clinical significance. Excessive and repetitive loading is a primary risk factor for the long-term failure of TKA components, specifically through polyethylene wear, which leads to particle-induced osteolysis and subsequent aseptic loosening [7, 8, 23].

Studies have consistently shown that higher BMI is correlated with increased rates of aseptic loosening and mechanical failure [5, 24]. By drastically reducing the mechanical load with every step, the bariatric surgery has likely improved the long-term survivorship prognosis for the patient's knee prosthesis [25, 26]. This mechanical relief, achieved without altering the fundamental gait kinematics, suggests that the primary benefit of late-stage weight loss is the direct reduction of cumulative stress on the implant, a factor critical for its longevity [27].

3.3. The Role of Bariatric Surgery and Weight Management in TKA

This case highlights the synergistic relationship between bariatric surgery and TKA. While the ideal timing remains a subject of debate, the benefits are clear. Performing bariatric surgery before TKA is associated with fewer perioperative complications, particularly infections [10, 11]. However, this case demonstrates a powerful argument for

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weight loss even after TKA. The significant reduction in joint loading can be framed as a long-term protective measure for the implant.

The emergence of highly effective anti-obesity medications, such as GLP-1 receptor agonists, provides another promising avenue. Recent studies indicate that medically induced weight loss is also associated with a lower risk of revision surgery and improved outcomes, offering a less invasive alternative to bariatric surgery for many patients [13, 14, 28]. The decision for weight management, whether surgical or medical, should be a central part of the conversation with any obese patient undergoing TKA, regardless of the timing.

3.4. Utility Of Wearable Sensors In Clinical Practice

This study underscores the value of using IMU-based wearable sensors for objective gait analysis in a clinical setting. Traditional functional tests like the TUG and 2MWT, while useful, failed to capture the most critical change in this patient: the massive reduction in joint loading. These tests showed stability, which could have been misinterpreted as a lack of change. The inertial sensor, however, provided the kinematic data (acceleration) that, when combined with the known change in mass, revealed the profound kinetic improvement.

As wearable technology becomes more accessible, validated, and user-friendly, it offers clinicians a powerful tool to look beyond simple timed metrics and gain deeper insights into the quality of movement and the biomechanical forces at play, allowing for more personalized and effective patient management [15, 16, 29, 30].

This is a single-patient case report, and the impact force calculation is an estimation based on acceleration. However, the use of a validated inertial sensor system provides objective, reproducible data that strengthens the clinical observations and generates important hypotheses for future, larger-scale studies.

4. Conclusion

In a patient with a stable functional recovery 6 months after TKA, subsequent massive weight loss via bariatric surgery did not alter the established kinematic gait patterns. However, it resulted in a profound and proportional reduction in the mechanical forces acting on the knee joint. This case demonstrates that the primary benefit of late-stage weight loss in the post-TKA population may be the significant biomechanical offloading of the prosthesis, rather than an immediate change in functional mobility scores. This highlights the synergistic potential of combining TKA and weight management strategies, whether surgical or medical, to optimize long-term joint health and implant survivorship.

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Competing Interests: Authors have declared that no competing interests exist.

Authors' Contributions: This case report was conducted through a collaborative effort among all authors. Author AMVT conceived and designed the study, coordinated the longitudinal follow-up, and led the development of the clinical and instrumented gait assessment protocol using the wearable inertial sensor approach. Author LPR, KCNC contributed to data acquisition and organization, supported the execution of the functional tests and gait assessments, and assisted in drafting the manuscript. Author RBP contributed to data curation, assisted with the preparation of figures/tables and interpretation of spatiotemporal outcomes, and revised the manuscript for methodological consistency. Author CS, HRSA provided clinical oversight of the orthopedic case context and contributed to the critical appraisal of the clinical narrative and interpretation of findings. Author CSO, VC supervised the project, reviewed the methodological and analytical approach, and provided critical revision for important intellectual content. All authors read and approved the final manuscript.

Consent: All authors declare that 'written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office of this journal.

Ethical Approval: The present study complies with the ethical guidelines and regulatory standards for research involving human beings established by the Brazilian National Health Council (Ministry of Health), originally issued in October 1996 and updated by Resolution No. 466/2012. The study was conducted after approval by the Research Ethics Committee under protocol number 6.775.127 and CAAE number 52052421.9.0000.5076. This is a prospective, observational, and comparative study, and all participants provided written informed consent, acknowledging that participation was voluntary, free of charge, and involved procedures of an experimental nature. Participants received all relevant information and were allowed to withdraw from the study or revoke their consent at any time without prejudice or harm. Absolute confidentiality of participants' identities was ensured in accordance with ethical principles of confidentiality and privacy. The study was carried out at a tertiary referral hospital specializing in rehabilitation, in partnership with a private university in the interior of Goiás, Brazil, which provided adequate technical infrastructure and institutional support to ensure successful completion of the project, including a fully equipped motion analysis laboratory and a portable, wireless G-Walk inertial sensor (BTS Bioengineering S.p.A., Italy).

Abbreviations

TKA: Total Knee Arthroplasty.
BMI: Body Mass Index.
TUG: Timed Up and Go (test).
2MWT: Two-Minute Walk Test.
IMU / IMUs: Inertial Measurement Unit(s).
AP: Antero-posterior.
PJI: Periprosthetic Joint Infection.
UHMWPE: Ultra-high molecular weight polyethylene.
GLP-1: Glucagon-like peptide-1 (as "GLP-1 receptor agonists").
CNPq: National Council for Scientific and Technological Development.
FAPEG: Goiás State Research Support Foundation.
HMAP: Municipal Hospital of Aparecida de Goiânia.
T1: First assessment time point (6 months post-TKA).
T2: Second assessment time point (12 months post-TKA).
L5: Fifth lumbar vertebra level (sensor placement site on the lower back).
kg / cm / m: Kilogram / centimeter / meter (units used for body mass, height, and distance).
s / min: Seconds / minutes (units used for test duration and cadence).
m/s / m/s²: Meters per second (speed) / meters per second squared (acceleration).
N: Newton (force unit used for estimated braking force).
L/R: Left/Right (used to report limb-specific indices).

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8.8 Resumo expandido publicado em periódico

8.8.1 Longitudinal Evaluation of Functional Mobility in Different Knee Prostheses Using an Inertial Sensor

Trindade AMV, Parreira RB, Rezende LP, Toledo RC, Moribayashi CAI, Silva FF, Nora FSA, Araujo HRS, Cimolin V, Oliveira CS. Longitudinal evaluation of functional mobility in different knee prostheses using an inertial sensor. Gait Posture. 2025;121 Suppl:214. doi: 10.1016/j.gaitpost.2025.07.230

Gait and Posture – Qualis Capes A2

Em estudo longitudinal foi avaliado o impacto de diferentes desenhos de prótese de joelho sobre a mobilidade funcional após artroplastia total. Trinta e seis pacientes com osteoartrose avançada submetidos a ATJ unilateral foram acompanhados aos 6 meses e 1 ano de pós-operatório, comparando próteses fixed-bearing (FB) e mobile-bearing (MB). A mobilidade foi mensurada por meio do teste Timed Up and Go (TUG) instrumentado com sensor inercial (G-Sensor®, BTS Bioengineering®) posicionado em L2, com extração de variáveis espaciotemporais (tempo total e velocidades nas sub-fases, especialmente durante os giros). A ANOVA de duas vias demonstrou melhora significativa do desempenho funcional em ambos os grupos entre 6 e 12 meses, sem diferenças estatisticamente significativas entre os tipos de prótese ($p > 0,05$). Observou-se, contudo, tendência consistente a maior rapidez nas tarefas de giro no grupo MB em comparação ao grupo FB após 1 ano, sugerindo possível vantagem biomecânica desse desenho em movimentos que exigem controle rotacional, embora ainda não comprovada estatisticamente.

Gait & Posture
Volume 121, Supplement, August 2025, Page 214

Longitudinal Evaluation of Functional Mobility in Different Knee Prostheses Using an Inertial Sensor

Andrei Machado Viegas Trindade [1], Rodolfo Borges Parreira [2], Leonardo Pinheiro Rezende [3], Roberta Carneiro Toledo [2], Christopher Atsushi Iwamoto Moribayashi [4], Fabio Felippe Silva [4], Fernanda Silva Azevedo Nora [5], Helder Rocha da Silva Araujo [6], Veronica Cimolin [7], Cláudia Santos Oliveira [*8]

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Research Question

Do different types of knee prostheses (FB and MB) affect functional mobility during longitudinal assessment? …

Methods

Thirty-six patients who underwent unilateral TKA for advanced knee osteoarthritis were evaluated at 6 months and 1 year postoperatively. Spatiotemporal variables (antero-posterior, latero-lateral, and vertical axes) were collected with an inertial sensor (G-sensor, BTS Bioengineering) positioned at L2 level during the Timed Up and Go (TUG) test assessment. We analyzed and compared the total time (in seconds) and sub-phases (time and velocity) of the TUG between the two types of prosthesis. …

Results

A two-way ANOVA indicated that both groups improved their TUG times after 1 year compared to 6 months; however, no significant differences were observed between groups ($p > 0.05$). Although patients with MB prosthesis tended to perform turning tasks more quickly than those with the FB prosthesis after 1 year, this trend was not statistically significant (Fig. 1). Despite the lack of significant differences between groups, our findings could suggest potential advantages for MB prostheses due to …

Discussion

The results indicate that prosthetic design may influence specific aspects of functional mobility, particularly in tasks that require turning. Despite the absence of statistically significant differences, the consistent trend toward faster rotational performance in the MB prosthesis group suggests a possible biomechanical advantage associated with its design which might highlight their potential benefits in dynamic movement. Importantly, the use of wearable inertial sensors enabled detailed …

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