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Original Research

Feasibility of a Preoperative Exercise and Nutritional Intervention in Sarcopenic Obese Individuals Undergoing Hip or Knee Arthroplasty: A Pilot Randomized Controlled Trial

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KEYWORDS
Exercise;
Feasibility study;
Nutrition;
Prehabilitation;
Protein;

Abstract *Objective:* To evaluate the feasibility and preliminary effectiveness of a combined preoperative exercise and nutritional intervention in patients with sarcopenic obesity (SO) scheduled for total hip or knee arthroplasty.
Design: A pilot randomized controlled trial was conducted (May 2021 to December 2022).
Setting: A regional Dutch hospital.

List of abbreviations: 6MWT, 6-minute walk test; AE, adverse event; ASMM, appendicular skeletal muscle mass; BIA, bioelectrical impedance analysis; BMI, body mass index; CST, chair stand test; DEXA, Dual-Energy X-ray Absorptiometry; HGS, hand grip strength; LROI, Dutch National Register of Orthopedic Interventions; OA, osteoarthritis; SAE, serious adverse event; SARC-F, strength, assistance with walking, rise from a chair, climb stairs, and falls; SO, sarcopenic obesity; THA, total hip arthroplasty; TJA, total joint arthroplasty; TKA, total knee arthroplasty; TUG, timed Up and Go test.

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Rehabilitation;
Sarcopenic obesity;
Total joint arthroplasty

Participants: Patients (N=40) with obesity before total hip arthroplasty or total knee arthroplasty (73% women, age 65±10y, body mass index, 34±3kg/m^2). Recruitment achieved a 25% success rate among contacted patients.
Interventions: Exercise, a physiotherapist-supervised program of resistance and aerobic training twice weekly for 6 weeks, plus dietitian-guided nutritional advice to reach recommended protein intake within the habitual diet (n=21), compared with a control group receiving usual preoperative care and general dietary guidance (n=19)
Main outcome measures: The main outcome was feasibility and acceptability, based on recruitment, adherence, and participant feedback. Secondary outcomes included physical function, self-reported health, body composition, and inflammation markers.
Results: Of 40 randomized patients, 25 completed the intervention period, with many dropouts because of scheduling issues related to coronavirus disease 2019. Exercise adherence was 80%, and dietary adherence was high, with participants significantly increasing protein intake. The proportion of patients meeting the recommended protein intake (1.2g/kg) increased from 21% to 93% in the intervention group, whereas it remained at 18% in the control group. Intervention participants improved preoperative functional mobility, with the timed Up and Go test reduced by a clinically relevant difference of 2 seconds. Interviews indicated that participants continued the nutritional advice and exercise on their own initiative after surgery. Postoperative outcomes, measured by length of stay and self-reported physical functioning, were unchanged.
Conclusions: Despite recruitment challenges and dropouts, the intervention was feasible and well-received, with short-term functional improvements. The preoperative period offers a valuable window for lifestyle changes, though no postoperative differences were observed. Longer or more personalized interventions may further enhance outcomes.

Many patients undergoing total joint arthroplasty (TJA) are overweight or obese. According to the Dutch National Register of Orthopedic Interventions (LROI), 42% of patients with total hip arthroplasty (THA) are overweight (body mass index [BMI], 25-30 kg/m^2) and 23% are obese (BMI >30 kg/m^2); in total knee arthroplasty (TKA), 42% are overweight and 39% are obese.[1] Similar trends are seen in the US, where obesity among TKA patients is projected to reach 69% in 2029.[2]. Because pain-related inactivity in OA contributes to both sarcopenia and weight gain, these patients are at risk for sarcopenic obesity (SO), the coexistence of excess body fat and low skeletal muscle mass and function.[3,4] Although preoperative weight loss is often advised, it can worsen outcomes if it leads to even more muscle loss or malnutrition.[5,6] The SO is associated with worse function and poorer recovery than obesity or sarcopenia alone.[4]

The combination of osteoarthritis (OA) and SO is common, with prevalence estimates ranging from 1.3% to 35.4% in knee OA and up to 18.4% in hip OA, depending on definitions.[7,8] Patients with SO undergoing TJA have a higher risk of complications and prolonged hospital stays, likely caused by reduced fitness and chronic inflammation.[4,9-11]

Combined preoperative exercise and nutritional strategies may help. Systematic reviews show that strength and aerobic training combined with increased protein intake can improve muscle function and body composition.[12,13] However, studies specifically addressing SO in TJA candidates are scarce.

This pilot study aimed to assess the feasibility of a combined preoperative protein-focused nutrition and exercise intervention in patients with SO scheduled for THA or TKA. Secondary aims were to evaluate preliminary effects on physical function, self-reported health, body composition, and inflammation marker levels.

Methods

Study design

This feasibility study used a randomized controlled design (design overview: supplemental appendix S1, available online only at http://www.archives-pmr.org/). Participants were randomized to the intervention or control group. Both received usual care; the intervention group additionally followed a 6-week prehabilitation program combining physiotherapist-supervised resistance and aerobic exercise with tailored nutritional counseling aimed at optimizing protein intake.

The protocol was approved by the Gelderse Vallei Hospital (BCWO 1911-074) and the Medical Ethics Review Committee (METC-WU, ABR: NL.72249.081.19). Written informed consent was obtained. The study complied with the Declaration of Helsinki and local regulations. Reporting followed the Consolidated Standards of Reporting Trials 2010 extension for pilot and feasibility trials.[14]

Participants

Patients scheduled for THA or TKA (May 2021-December 2022) at the Gelderse Vallei Hospital were recruited. Inclusion criteria were as follows: (1) OA diagnosis requiring THA/TKA; (2) obesity (BMI ≥30kg/m^2) and muscle weakness per Cruz-Jentoft et al[15] criteria; and (3) age ≥18 years and adequate cognition.

Exclusion criteria

Severe comorbidities contraindicate exercise or surgery[16,17] and a glomerular filtration rate <30 mL/min/1.73m^2.

Recruitment

Eligible patients awaiting THA or TKA were identified from the hospital waiting list and consecutively invited to participate. They were provided with a written information letter and subsequently contacted by telephone to provide further explanation and answer any questions regarding study participation. Patients with interest were then screened for SO during the same phone call. Screening included self-reported BMI, which was cross-checked against electronic patient records, and completion of the SARC-F (strength, assistance with walking, rise from a chair, climb stairs, falls) questionnaire to assess risk of sarcopenia. Positive cases (SARC-F score $\geq$4 and BMI >30kg/m^2) were then tested for muscle strength and weighed during the standard preoperative screening by hand grip strength (HGS) and chair stand test (CST, 5 repetitions). Patients with obesity and muscle weakness (HGS score <27kg for men, <16kg for women, or CST >15s) were invited to provide informed consent. Thereafter, the patients received the standard preoperative screening supplemented with some baseline tests.

Randomization and blinding

Participants were randomized using Castor electronic data capture[a] (Castor EDC, Ciwit B.V.), applying validated block randomization with stratification by sex and joint type (hip vs. knee). Because of the intervention's nature, blinding was not possible for patients, physiotherapists, or dietitians.

Usual care

Both groups received usual care. Usual preoperative screening included physical and health assessments. Patients were educated on staying physically active[18] and advised on physical therapy if needed.[19,20] The content of this physiotherapy was left to the physiotherapists in our network and usually consists of advice and/or exercise therapy. Nutritional risk was assessed with the SNAQ, with dietitian referral for scores $\geq$3.[21] All participants had access to information on the Dutch dietary guidelines, and the control group got general nutritional advice, including protein advice (in a short brochure). The advice focused on ensuring adequate daily protein intake, emphasizing the distribution of protein-rich meals and snacks throughout the day and a minimum of 25 g of protein per main meal to support muscle protein synthesis. Additional protein after training and several practical examples of protein-rich foods for each eating occasion were provided. THA was routinely performed via the direct anterior approach. Early postoperative mobilization was applied, and the planned hospital stay was 1-2 nights. Surgical scheduling varied because of coronavirus disease 2019 (COVID-19); waiting lists were longer, and urgent cases were prioritized if last-minute slots became available.

The intervention group

Participants followed a 6-week exercise and protein-rich diet program. Supervised sessions (2×/wk, 30-60min) included resistance and aerobic training per Dutch OA and American College of Sports Medicine guidelines (supplemental appendix S2, available online only at http://www.archives-pmr.org/).[16,21-23] Key components of the exercise program were as follows: (1) resistance training: major muscle groups combined with functional training (60%-80% of the 1-repetition maximum, or 50%-60% for beginners or frail patients; 8-15 repetitions; 2-4 sets; 30-60s rest); and (2) aerobic training (>60% of estimated maximum heart rate, or 40%-60% for beginners). The hospital's network of trained physiotherapists supervised the sessions and tailored them to each individual's needs. Therapists completed evaluations after weeks 3 and 6.

Dietitians reviewed food diaries to tailor advice. Protein goal: 1.2 g/kg adjusted body weight (based on height and BMI 27.5kg/m^2). This approach prevents overestimation of protein needs in obesity.[12,24] Fat and carbs were substituted for protein to maintain caloric balance and prevent big weight changes.[4,25]

Additional protein intake recommendations: 25-30 g per meal and 20 g before bed and after exercise.[12,26]

Outcome measures

Data were collected at recruitment (T0), during (T1, after 3wk, only intervention group), and after (T2, after 6wk) the intervention, at discharge (T3), and 6 weeks post-op (T4) (supplemental appendix S2).

Main outcome measure: feasibility and acceptability

Recruitment and dropout data, including reasons for nonparticipation, were collected. The SO diagnosis accuracy was assessed using Dual-Energy X-ray Absorptiometry (DEXA) confirmation (table 1, step 3). The DEXA and bioelectrical impedance analysis (BIA) correlation was evaluated. Sarcopenia was defined as appendicular skeletal muscle mass index (ASMMI)/height^2 <7.0 kg/m^2 (men) or <5.5 kg/m^2 (women) plus BMI >30 kg/m^2.[15] Godziuk et al.'s[27] cutoff (HGS <0.65kg for women, <1.1kg for men) was also explored.

Furthermore, acceptability measures included: (1) contraindications for exercise: physical activity readiness questionnaire and comorbidities; (2) exercise adherence: number of sessions attended and intensity achieved, as reported by physiotherapists through a questionnaire; and (3) diet adherence: protein consumption, food diary completion, and attendance at dietary consultations. Protein and energy intake were assessed using 3-day food diaries, completed on 3 consecutive days, including 1 weekend day. Diaries were reviewed and analyzed using the Dutch Food Composition Table (NEVO 7.0)[28]; (4) patient appreciation and motivation; (5) health care provider insights. Patient appreciation and motivation were assessed using Likert scales (T1, T2). To complement the quantitative data, we conducted brief exploratory, semistructured interviews poststudy with a purposive sample of participants and health care providers. Although interviews were not audio-recorded or formally transcribed, field notes were taken to capture key points. These notes were informally reviewed for recurring insights to support the interpretation of the study outcomes; and (6) adverse events (AEs): monitored and recorded in the study files as serious AEs (SAEs) or nonserious AEs when reported by patients or observed by the researchers during the assessment visits.

Table 1 Measurements to find and confirm cases of SO and malnutrition (SNAQ) from all patients who completed the baseline measurements (n=31).

Variables	Measurement	Cut Points	Participants with Positive Score ($n^{positive}/n^{total}$) AT T0
Stages of defining SO by Cruz et al[15]			
Find cases	SARC-F	≥4	31/31
Assess muscle strength	Grip strength (kg)	M <27	1/8
		F <16	5/16
	Chair stand test 5x (s)	>15	30/31
Confirm muscle quality or quantity	ASMMI (kg/m^2, DEXA)	M <7.0	1/8
		F <5.5	0/23
	ASMMI (kg/m^2, BIA)	M <7.0	0/7
		F <5.5	0/20
Severe physical performance	TUG test (s)	>20	2/31
	6MWT	<400m	25/28
Additional screening instruments			
Obesity	BMI (kg/m^2)	≥30	29/31
Malnutrion[21]	SNAQ	>1	0/31
Muscle strength[27]	Relative grip strength (kg/m^2)	M <1.10	3/8
		F <0.65	8/23
Body composition[3]	Fat mass (%, DEXA)	M >31	6/8
		F >43	16/23
Body composition[3]	Appendicular lean mass adjusted to body weight (%, DEXA)	M <25.7%	4/8
		F <19.4%	2/23

Abbreviations: SNAQ, short nutritional assessment questionnaire.

Secondary outcomes

Preoperative outcomes were as follows: physical functioning: (1) HGS, CST, 6-minute walk test (6MWT) and Timed Up and Go (TUG) conducted by trained physical therapists or research assistants[15,29]; (2) self-reported health: patient-reported outcome measures as recommended by the Dutch Arthroplasty Registry (LROI): hip/knee osteoarthritis outcome score, Oxford hip/knee score, the EuroQol 5-dimension questionnaire health score (scale 1-100), and pain scores of the past week at rest and during activity (visual analog scale 1-10)[1]; (3) body composition: ASMMI using DEXA and BIA (Bodystat 500). Measurements before February 2022 used the Hologic Discovery A, whereas subsequent measurements used the Hologic Horizon A. Patients were scanned on the same device for both measurements, and blood samples were taken for inflammation marker levels of C-reactive protein (CRP) and interleukin-6 (IL-6). These inflammation marker levels may be reduced by interventions for sarcopenia and/or obesity.[30-32] Levels of IL-6 above 6 pg/mL[33] and of CRP mg/L above 5[34] were considered high.

Postoperative outcomes were length of hospital stay, discharge destination (home or rehabilitation center), use of postoperative care, and patient-reported outcome measures as recommended (T4).

Statistical analysis

As a pilot study, no power calculation was conducted; a sample size of 34 was considered feasible and adequate (17 per group). Recruitment and adherence were reported using frequencies and proportions. Outcomes were summarized with means (±standard deviation [SD]), medians (interquartile range), or frequencies and proportions as appropriate. Given the small sample size, no hypothesis testing was performed; instead, 95% confidence intervals were reported. The focus was on clinically relevant differences.[35] Analyses were conducted using SPSS (version 27) and R (version 4.4.0).[b] Preoperative intervention analysis included participants who trained for at least five weeks, using complete case analysis without imputation. Pearson's correlation coefficient assessed agreement between ASMMI using BIA and DEXA.

Results

Patient flow

A total of 360 patients with a self-reported BMI >30 kg/m^2 (67% women, 68±9y) were informed about the study (figure 1). Of these, 91 (66% women, age 65±9y) expressed interest, whereas 269 declined, mainly because of lack of interest or motivation (table 2). Of the 91 interested, 56 were eligible for physical screening after a phone-based check of inclusion criteria (exclusions: SARC-F score <4, n=31; no obesity, n=2; and surgery <6wk, n=2). After physical screening, 16 patients were excluded (no muscle weakness, n=12; and other reasons, n=4). In total, 40 patients (73% women age 65±10y, table 3) provided informed consent and were randomized into the intervention (n=21) or control (n=19) group. Groups were comparable at baseline except for physical performance (table 3).

Nine patients dropped out before the additional baseline measurements (protocol violations) 0 and during the

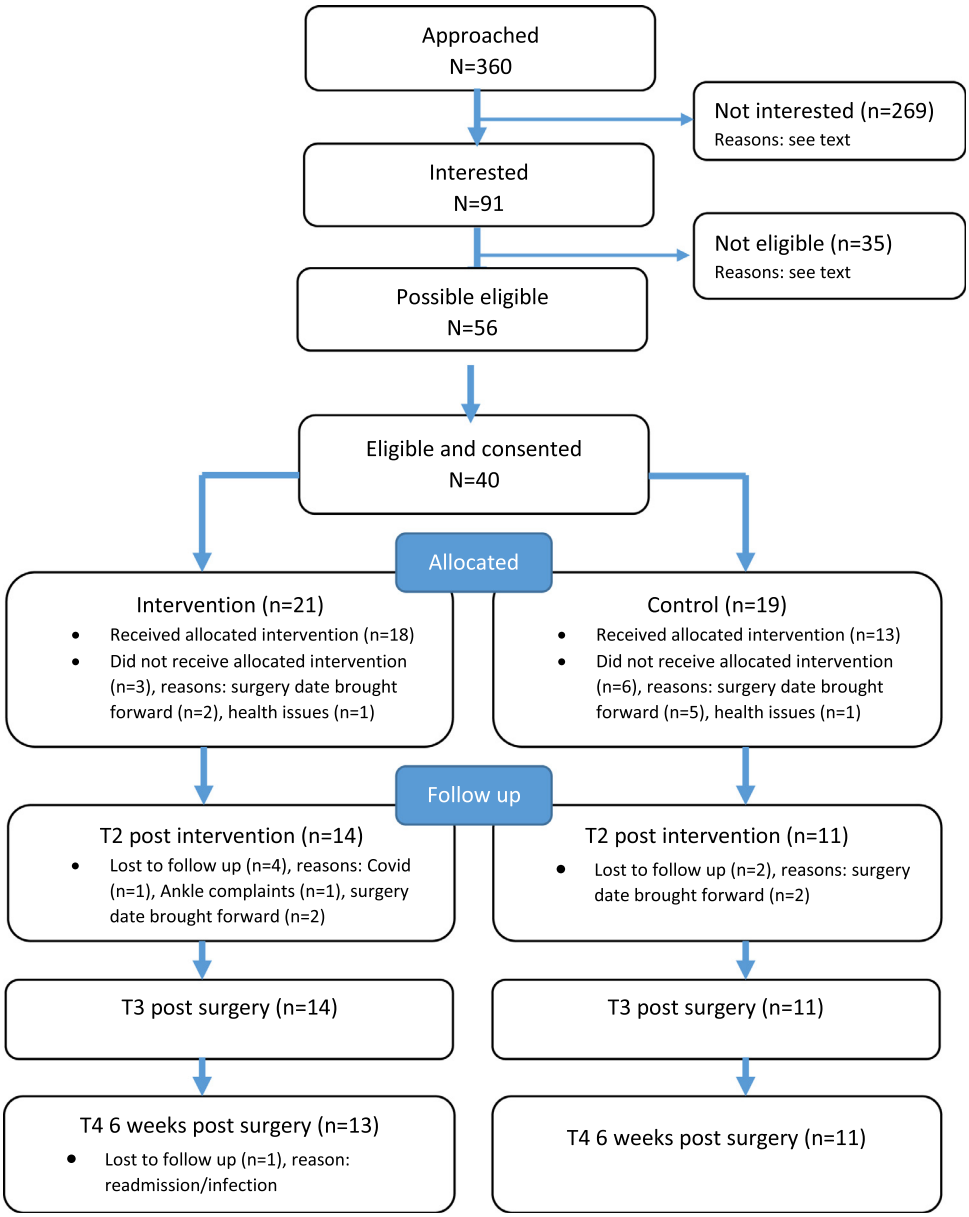

Fig 1 Flow chart of the study.

intervention, another 6 dropped out, mainly because of surgery timing. Finally, 25 participants completed the preoperative protocol and underwent surgery (2021-2023). Time from T2 to surgery varied widely (1-330d; median, 8) because of COVID-19-related scheduling issues.

Data collection and measurements

Missing baseline (see table 4 for numbers) data for CRP and IL-6 levels, food intake, and DEXA were mainly because of cancellation of the second visit after early dropout. BIA data were missing for 3 patients: equipment failure (n=2) and poor documentation (n=1). Most physical tests were feasible, though some data were missing when patients could not complete tests. Three 6MWT results were not obtained

Table 2 Participant-reported reasons for nonparticipation during recruitment (n=269).

Reason*	N
Lack of interest or motivation	79
Time constraints	62
Being too fit	35
Inability to exercise	26
Health issues	25
Transport issues	20
Engagement in other exercise programs	15
Uncertain surgery dates	15
Prior experience with surgery ("I know what to do")	11
Language barriers	4
Unspecified reasons	24

* Multiple reasons could be given (n=47).

Table 3 Baseline characteristics of the 40 initial randomized patients.

Characteristic	All Participants	n	Intervention	n	Usual Care	n
General						
Age, y (mean±SD)	65±10	40	66±10	21	65±9	19
Sex (% [n] female)	73 (29)	40	71 (15)		74 (14)	
Surgery (% [n] knee)	70 (28)	40	71 (15)		68 (13)	
ASA score		40		21		19
I (%)	3 (1)		5 (1)		0 (0)	
II (%)	60 (24)		52 (11)		68 (13)	
III (%)	37 (15)		43 (9)		32 (6)	
Physical functioning						
6MWT, m	307± 69	35	281±65	19	338±62	16
Chair rise time, s	17.0 (12.3-31.5)	27	14.7 (12.3-31.5)	14	17.0 (12.6-20.2)	13
Handgrip strength, kg	30 (5-66)	40	29 (6-50)	21	30 (5-66)	19
TUG, s	10.87 (5.97-25.90)	40	12.02 (6.78-25.90)	21	10.05 (5.97-15.59)	19
Body composition and inflammation marker levels						
ASMMI/BMI (DEXA)	0.22±0.02	30	0.23±0.02	17	0.22±0.02	13
BMI, kg/m^2	34± 3	40	35±4	21	34±3	19
CRP, mg/L	4 (4-32)	32	5 (4-32)	18	4 (4-11)	14
IL-6, mg/L	0.27 (0.04-17.7)	31	0.54 (0.04-17.73)	18	0.04 (0.04-2.22)	13
Nutrition						
Caloric intake, g/d	1651±357	33	1638±327	19	1667±407	14
Protein intake, g/d	98 (83-139)	34	99 (83-121)	20	97 (86-139)	14
SNAQ	0±0	39	0±0	20	0±0	19
Self-reported health						
OHS, 0-48	14.5 (7-33)	12	13.5 (7-33)	6	22 (14-29)	6
OKS, 0-48	20 (7-33)	28	21 (8-33)	15	17 (7-31)	13
HOOS total score,	13 (9-17)	12	14.5 (11-17)	6	12 (9-16)	6
KOOS total score,	19 (11-25)	28	19 (12-23)	15	19 (11-25)	13
Pain rest, 0-10	5.8±2.3	40	5.1±2.4	21	6.5±2.1	19
Pain activity, 0-10	7.7±1.7	40	7.7±1.6	21	7.7±1.9	19

Data are mean (±SD), unless otherwise stated.
Abbreviations: ASA, American Society of Anesthesiologists; HOOS, hip disability and osteoarthritis outcome score; KOOS, knee disability and osteoarthritis outcome score; OHS, Oxford hip score; OKS, Oxford knee score; SNAQ, short nutritional assessment questionnaire.

because of pain or fatigue, and 2 patients declined additional blood draws.

Among 31 patients with complete baseline data, muscle weakness was confirmed by low HGS score (n=6) and poor CST score (n=30). Only 1 had confirmed sarcopenia on DEXA (low ASMMI; table 1). Two patients with BMI just below 30 kg/m^2 (29.1 and 29.4kg/m^2) were included because of their initial self-reported BMI and high motivation. Correlation between DEXA ASMMI and BIA ASMMI, HGS, and HGS/BMI was 0.84, 0.72, and 0.61, respectively (all $P<.05$).

Contraindications for exercise

Twenty-one patients (21/40, 53%) reported comorbidities: cardiovascular (n=7), diabetes (n=5), pulmonary (n=5), and other conditions (n=8). On the physical activity readiness questionnaire, 25 of the 40 (63%) patients scored ≥1, mostly related to OA, back pain, or antihypertensive medication. Medical records and pre-op anesthesiology screenings were reviewed. In five cases, specialist consultation was required: anesthesiologists (n=4), orthopedic surgeon (n=1), cardiologist (n=2), and rehabilitation physician (n=1). All participants were confirmed to have no contraindications.

Adherence to the exercise and diet

In the intervention group, 80% of physiotherapy sessions were attended; absences were because of holidays, illness, or scheduling issues. The intervention lasted a mean of 43 days (±SD, 7; range 5-9wk), with a mean of 10 sessions (±SD, 2). Of the 14 participants who completed the intervention, 11 (79%) reached the targeted intensity for resistance exercises and 13 (93%) for aerobic exercises. Barriers included flu recovery, hip pain, medications, and low baseline fitness. In the control group, 6 of 13 (46%) reported some form of presurgery training: 2 with a physiotherapist, 2 at home, and 2 at the gym.

Dietary consultation and food diary completion rates were 100% at T0 for both groups, 100% at T1 (intervention group), and 90% at T2 for both. Protein intake in the intervention group rose by 45%, reaching 124 g/day on average (fig 2).

No notable increase occurred in the control group. At baseline, 3 intervention patients (21%) and 2 controls (18%) met the 1.2 g/kg protein target. By T2, 13 (93%) of intervention participants reached the target vs. 2 (18%) in the control group. Despite slightly higher energy

Table 4 Patient outcomes on baseline, T2, and T4.

	Intervention						Control					
Charateristic	Baseline	n	T2	n	T4	n	Baseline	n	T2	n	T4	n
Physical functioning												
6MWT, m	286±70	13	303±52	13			363±59	9	370±60	9		
Chair rise time, s	13.0 (12.3-31.5)	8	15.1 (9.5-31.4)	13			17.3 (12.6-20.2)	8	17.9 (14.0-28.4)	10		
Chair rise time <15 s, n(%)	1 (7%)	14	6 (43%)	14			0		3 (27%)	11		
Handgrip strength, kg	30 (10-50)	14	29 (18-57)	14			30 (5-66)	11	30 (11-60)	11		
TUG, s	11.81 (6.78-20.35)	14	9.90 (7.21-23.95)	14			8.56 (5.97-13.23)	11	10.02 (7.42-12.05)	11		
Body composition and inflammation marker levels												
ASMMI/BMI	0.25±0.02	11	0.22±0.02	10			0.23±0.02	10	0.23±0.02	10		
BMI, kg/m^2	35±3	14	35±3	14			34±2	11	33±2	11		
CRP, mg/L	5 (4-27)	12	4 (4-27)	13			4 (4-11)	11	4 (4-11)	11		
IL-6, mg/L	0.6 (0.04-3.0)	12	0.3 (0.04-6.1)	13			0.04 (0.04-1.0)	10	0.03 (0.04-0.7)	11		
Nutrition												
Caloric intake, g/d	1740±266	14	2088±538	14			1783±347	11	1687±422	11		
Protein intake, g/d	101 (83-121)	14	125 (103-161)	14			96 (86-139)	11	80 (57-131)	11		
Self-reported health												
OHS, 0-48	13.5 (8-33)	4	8 (7-26)	3			22 (17-27)	2	23 (23-23)	1		
OKS, 0-48	20.5 (8-30)	10	23 (11-29)	10			17 (9-31)	9	19 (13-40)	8		
HOOS total score,	14.5 (11-17)	5	15 (13-16)	4	8 (0-51)	4	13 (11-15)	2	14 (13-15)	2	9 (7-11)	2
KOOS total score,	19 (12-21)	10	17 (6-22)	10	11 (9-16)	9	17 (11-25)	9	16.5 (6-24)	8	14 (7-18)	9
Pain rest, 0-10	5.4±2.0	14	4.9±2.2	14	2.2±2.6	13	6.1±2.3	11	5.6±1.7)	10	2.2±1.9	11
Pain activity, 0-10	7.5±1.5	14	7.7±1.1	14	3.5±2.3	13	7.4±2.3	11	7.4±1.7	10	3.7±2.1	11

Values are presented as mean±SD for normally distributed data or as median (minimum-maximum) for nonnormally distributed data unless stated otherwise.
Abbreviations: HOOS, hip disability and osteoarthritis outcome score; KOOS, knee disability and osteoarthritis outcome score; OHS, Oxford hip score; OKS, Oxford knee score.

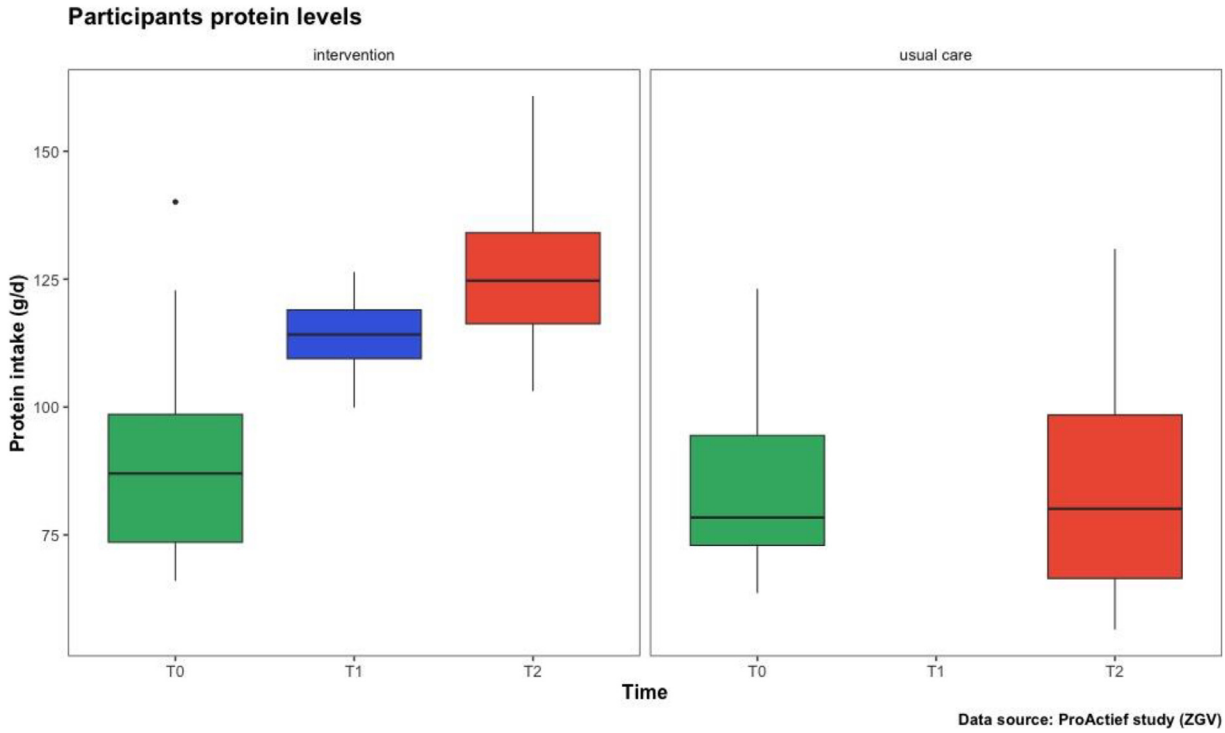

Fig 2 Protein intake in the intervention group and control group at T0 (baseline), T1 (after 3wk intervention), and T2 (after 6wk intervention).

intake, BMI and body composition remained stable in the intervention group.

Patients' appreciation and motivation

Participants in the intervention group reported high satisfaction with the physiotherapy component (table 5). Of the 9 interviewed participants, 8 reported positive effects, primarily in muscle strength (n=8), aerobic fitness (n=4), and confidence in recovery postsurgery (n=3). They noted easier daily activities, such as rising from a chair. All were willing to recommend the program, with 3 suggesting it especially for physically unfit or older individuals. Satisfaction with the dietary component was also high. Participants felt more motivated to increase protein intake, and 8 reported added benefits when combining dietary changes with physiotherapy.

After the intervention, 8 participants continued physiotherapy or home exercises, and 8 maintained higher protein

Table 5 Patient evaluation of the intervention at T1 and T2, using Likert scales (mean [range]).

Physiotherapy	T1 n=13	T2 n=14
I was motivated for the training	5 (1-5)	5 (5-5)
Adhering to the advice to stay physically active was time-consuming	2 (1-4)	2 (1-5)
The physiotherapy was difficult/heavy	4 (1-5)	4 (1-5)
I had fun doing the exercises during physiotherapy	4 (1-5)	5 (2-5)
It was useful to train with the physiotherapist twice a week	5 (4-5)	5 (4-5)
Because of the physiotherapy, I'm better prepared for my surgery	4 (3-5)	4 (4-5)
The reason for doing the physiotherapy is clear to me	5 (4-5)	5 (4-5)
My physical complaints hinder my training performance	4 (2-5)	4 (2-5)
Diet	**n=13**	**n=14**
I was motivated to consume more protein	5 (4-5)	5 (1-5)
Adhering to the dietary advice was time-consuming	2 (1-5)	2 (1-4)
I found it difficult to consume more protein	2 (1-5)	2 (1-5)
The (telephonic) appointments with the dietician motivated me to consume more protein	5 (4-5)	5 (4-5)
It was useful to consume more protein	5 (3-5)	5 (4-5)
Because of the high protein consumption, I'm better prepared for my surgery	4 (3-5)	4 (3-5)

5=strongly agree, 4=agree, 3=undecided, 2=disagree, 1=strongly disagree.

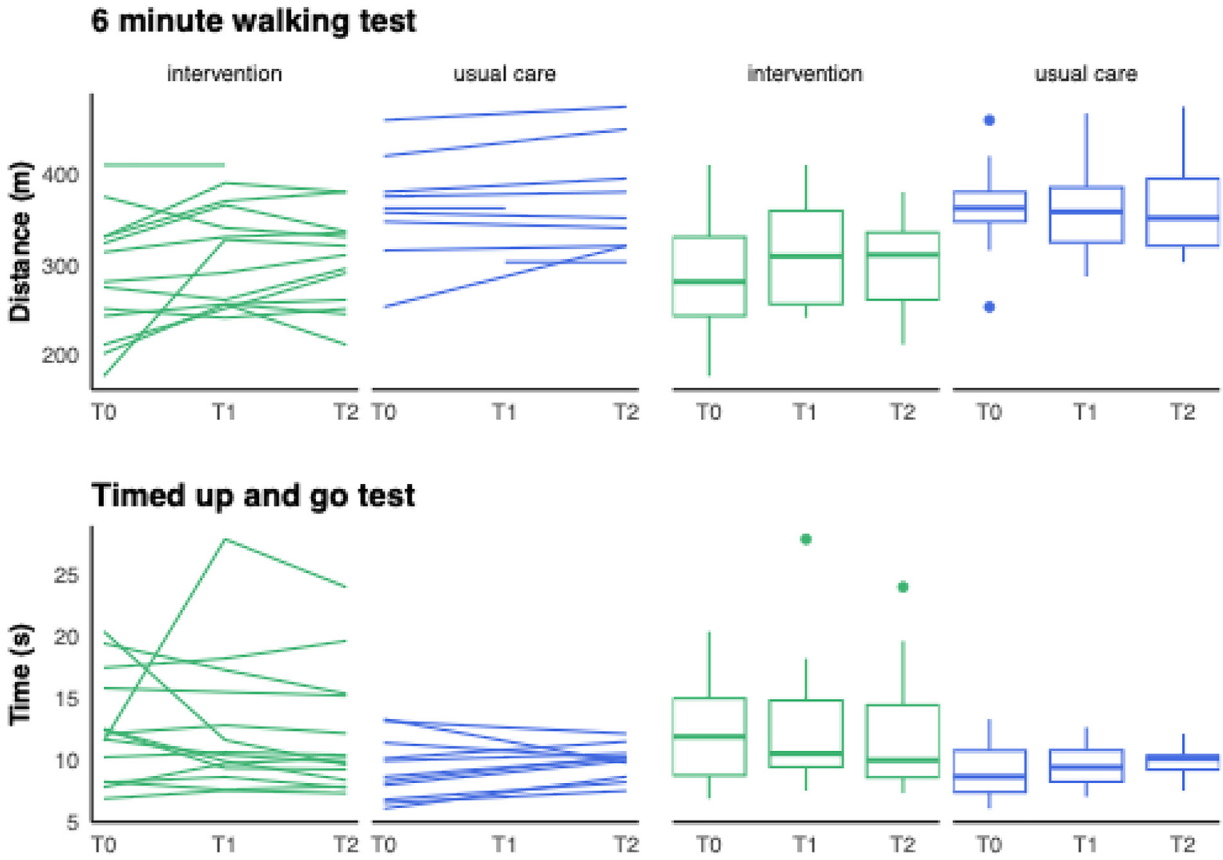

Fig 3 Individual and group outcome of the 6MWT and TUG test of patients at T0 (baseline), T1 (3wk intervention), and T2 (6wk intervention) (n=25).

intake. Familiarity with both elements during the intervention made it easier to sustain them postoperatively. One participant stopped physiotherapy because of the costs.

Health care provider insights

Four physiotherapists were interviewed and reported overall satisfaction with the intervention and noted improvements in patients' strength. They observed that patients with severe OA often showed fear and uncertainty, highlighting the need for emotional support alongside physical training. The dietician reported that patients had many nutrition-related questions beyond protein intake, emphasizing the value of broader dietary education for surgical preparation. However, she noted that meaningful dietary changes were difficult to achieve within just 2 consultations, and that patient motivation was key to success.

Adverse events

No SAEs occurred during the intervention. Seven patients reported exercises to be heavy or painful, especially cycling or treadmill walking. No participants discontinued exercise; however, adjustments were made to accommodate comorbidities or disabilities.

Postoperatively, 2 SAEs occurred in the intervention group: 1 readmission because of infection within 6 weeks and another because of increased pain after an initially normal recovery.

Secondary outcome

Preoperative changes in body composition, physical function, self-reported health, and inflammation markers are shown in figure 3 and table 4 (for the 25 patients who completed the intervention).

After the intervention, 6 of 15 patients in the intervention group completed the CST within 15 seconds, vs. 3 of 11 in the control group. TUG time improved by nearly 2 seconds in the intervention group and 1.5 seconds in controls. The 6MWT improved by 17 m in the intervention group vs. 7 m in controls (fig 3 and table 4).

One patient in the intervention group had an elevated IL-6 level (3.0-6.1pg/mL) without symptoms. Elevated CRP level was seen in 5 (T0) and 4 (T2) patients in the intervention group and in 4 (T0) and 3 (T2) patients in the control group. No other relevant changes were observed between T0 and T2 in either group (table 5).

Postoperative outcome

Seventy-six percent of the patients were discharged on postoperative day 1. No relevant differences in postoperative

Table 6 Postoperative outcomes at T3 (at discharge) and T4 (6 weeks after surgery).

Outcome	Total	n	Intervention	n	Control	n
Functioning independently day 1 (%)	85		90		80	
Length of hospital stay (h)	**27.5 (20.5-77)**	**25**	**27.3 (20.5-74)**	**14**	**28.0 (22.2-77)**	**11**
Length of hospital stay (d) (%)						
1	**76**	**19**	**72**	**10**	**82**	**9**
2	**12**	**3**	**14**	**2**	**9**	**1**
3	**12**	**3**	**14**	**2**	**9**	**1**
Recovered at home (%), T4	88	22	78	11	100	11
GP visits (%), T4						
0	74	17	75	9	73	8
1	17	4	25	3	9	1
2	9	2	-	-	18	2
Physiotherapy visits (n), T4	6 (0-12)	24	6 (0-12)	13	6 (4-12)	11
NSAIDs use (d), T4	0 (0-42)	23	0 (0-42)	12	0 (0-42)	11
Opioid use (d), T4	14 (0-42)	24	14 (0-42)	13	14 (4-28)	11

All are medians (range), unless stated otherwise.
Lenght of hospital stay is the number of nights spend in hospital from surgery till discharge.
Abbreviations: GP, general physician; NSAID, nonsteroidal anti-inflammatory drug.

outcomes were observed between the intervention and control groups (tables 4 and 6).

Discussion

This study assessed the feasibility and preliminary effectiveness of a combined preoperative protein-focused nutrition and exercise intervention for patients with OA and SO scheduled for TJA. Despite recruitment difficulties and notable dropouts, the intervention was feasible and well-accepted. Participants increased dietary protein to recommended levels and showed clinically relevant improvements in functional mobility.

Although literature exists on combined interventions in older adults with SO[13] or on prehabilitation in orthopedic patients with either sarcopenia,[36] obesity,[37] malnutrition,[38] or in general orthopedic patients,[39] this is the first study to investigate a multimodal intervention in patients with SO before TJA. It is important to note that sarcopenia was formally confirmed using DEXA or BIA only in a few patients based on the cutoffs proposed by Cruz et al.[15] Therefore, our study population is better described as patients with "probable SO" or obesity with muscle weakness rather than confirmed SO. More recent literature also acknowledges that other cutoff points are needed for obese patients to confirm SO.[3,27] Despite the unconfirmed sarcopenia in many of our study population, their high BMI and poor functional status do indicate that they are patients at high risk of delayed recovery.[5,9,19]

Feasibility and acceptability

Recruitment was challenging: only 25% (91/360) of the approached patients expressed interest, and 25 of 40 randomized patients completed the intervention. COVID-19-related (March 11, 2020 to May 5, 2023). Scheduling issues contributed significantly to drop out, emphasizing that hospital planning often outweighs prehabilitation efforts. Similar challenges are reported in other prehabilitation studies, underscoring the need for enhanced recruitment strategies, including social support, patient education, and clinician involvement.[40,41]

Nevertheless, acceptability was high. Exercise was feasible, and adherence was good, with 80% of physiotherapy sessions attended, comparable to other programs.[42] Dietary adherence was also strong. Participants significantly increased protein intake to recommended levels without supplements, supported by a dietitian's guidance. A systematic review by Yee et al[43] concluded that dietitian-led nutritional interventions are both feasible and beneficial for improving outcomes after TJA, likely offering more consistent benefits than supplementation alone.

Preliminary effect on physical functioning and body composition

The intervention produced encouraging but modest effects on physical functioning. Functional mobility improved in the intervention group, with a clinically relevant 2-second TUG improvement, whereas the control group declined by 1.5 seconds.[35] These findings align with previous studies showing that even short-term, well-structured exercise programs can enhance preoperative functional mobility.[39]

However, no significant gains in muscle strength or mass were observed, likely because of the short intervention duration, measurement limitations, and comorbidities restricting training intensity. The short intervention duration may have limited detectable changes in body composition, especially in patients with OA with comorbidities that constrained training intensity. Interventions of 12-24 weeks may be required for meaningful effects.[12,13] Moreover, the standard care pathway, which already emphasizes physical

activity and early mobilization, may have minimized further short-term postoperative differences between groups.

Importantly, our intervention targeted protein intake only and did not include weight loss, even though obesity is a well-known risk factor for impaired recovery, chronic low-grade inflammation, and metabolic dysfunction after arthroplasty.[2,4,30] Recent systematic reviews demonstrate that preoperative weight loss interventions can significantly reduce body weight and BMI before surgery and may lower postoperative complications.[37] Yet, isolated weight loss risks accelerating muscle loss in older adults, which could worsen sarcopenia.[6] Therefore, combined interventions focusing on weight reduction alongside muscle preservation or hypertrophy—through resistance exercise and high-quality protein intake—may be essential for optimal outcomes in patients with obesity and probable sarcopenia.[3,6,12] Future trials should evaluate whether integrating weight loss strategies into multimodal prehabilitation can maximize both functional and surgical recovery.

Implications for clinical practice

This study provides insight into designing interventions for patients with OA and SO. High adherence and positive reception support the feasibility of combining exercise and nutrition in preoperative care. Surgery may act as a "teachable moment" when patients are more motivated to improve their lifestyle.[44] Interviews confirmed that many participants continued exercising and monitoring their diet postoperatively.

The limited effects on physical function and self-reported health underscore the need to better identify high risk patients, optimize intervention duration and intensity, and consider more personalized approaches. Longer prehabilitation may better address patient needs and allow time for changes in body composition. Ideally, interventions should start during conservative OA treatment to prevent or reduce SO, and lifestyle modifications should continue postoperatively.

This study also highlighted the importance of assessing and promoting protein intake presurgery. Few participants met the recommended intake at baseline, but nearly all in the intervention group achieved the target through diet alone. Personalized nutritional guidance was essential, as general advice given to the control group failed to increase intake.

Study limitations

This study has several limitations. First, selection bias may have occurred, as participants were likely more motivated than those who declined because of disinterest, low motivation, or health issues. Second, the COVID-19 pandemic disrupted surgical planning and intervention delivery, potentially influencing outcomes and dropout rates. Third, the screening strategy we used for SO was not suitable for this obese population.[15] Finally, the absence of postoperative inflammation and physical performance data limited the assessment of long-term effects.

Some additional limitations are inherent to the pilot nature of the study. The sample size was intentionally small and not powered to detect effects on gross joint replacement outcomes. Likewise, the relatively high proportion of dropouts, while important to acknowledge, is common in early-phase feasibility studies.

Conclusions

This pilot study supports the feasibility and acceptability of a combined preoperative protein-focused nutrition and exercise intervention for motivated patients with OA and SO undergoing TJA. Improvements in diet, functional mobility, and positive participant feedback suggest potential for enhancing preoperative care and leveraging the surgical period as a teachable moment for lifestyle change. Future research should focus on optimizing recruitment, tailoring interventions, and evaluating cost-effectiveness for improving postoperative outcomes and long-term health in the growing population of obese patients who have undergone TJA.[2]

Suppliers

a. Castor electronic data capture; Castor EDC.
b. SPSS, version 27; IBM.

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Authorship Contributions /CRediT statements

All authors had a substantial contribution to the conception of this study, reviewed it critically, and gave final approval of the version to be published. They agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. EO: conception and design, analysis and interpretation of the data, drafting of the article, obtaining of funding, collection of data, MH: conception and design, interpretation of the data, critical revision of the article for important intellectual content, collection of data. JE: analysis and interpretation of the data, critical revision of the article for important intellectual content, and statistical expertise. HH: critical revision

of the article for important intellectual content. MM: conception and design, interpretation of the data, critical revision of the article for important intellectual content. JZ: conception and design, interpretation of the data, and critical revision of the article for important intellectual content.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

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

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