End-stage knee osteoarthritis with and without sarcopenia and the effect of knee arthroplasty – a prospective cohort study

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Abstract

Background:

Sarcopenia often accompanies osteoarthritis (OA) which is managed by total knee arthroplasty (TKA) in late stage. Recent studies have suggested higher risk of post-operative complication after TKA in sarcopenic OA subjects but whether TKA can benefit them as for non-sarcopenic subjects remain unexplored. This study aims to examine the dynamic, mutual impact of sarcopenia and TKA in their one-year post-operative period.

Methods:

This prospective cohort study was conducted between 2015 to 2018 at our hospital. Patients with end-stage OA of the knee waiting for TKA were recruited into the study. Primary outcome measures were change in muscle strength, mass and function. Secondary outcome measures were Quality of Life (QOL) measurements in pain, psychological and physical health.

Results:

Fifty-eight patients were recruited, of which 79.3% were female and 32.8% already had sarcopenia at baseline. The average age of sarcopenic subjects and non-sarcopenic subjects were comparable (67.89±7.07 vs. 67.92±6.85; p=0.99) and sarcopenic subjects had lower body mass index (BMI) (25.64±2.64 vs. 28.57±4.04; p=0.01). There was a statistically significant improvement in walking speed (10.24±5.35 vs 7.69±2.68, p<0.01) and muscle strength in both sarcopenic and non-sarcopenic patients after TKA. This was accompanied by an improvement trend in muscle mass in all subjects. There was no change in handgrip power before and after TKA and subsequent follow-up (p=0.97). Quality of life measured with WOMAC, SF12v2 and IPAQ revealed progressive significant improvement ($p \leq 0.01$). Further analysis at the IPAQ also found increased engagement of high-intensity activities.

Conclusions:

This study showed that sarcopenia among patients with end-stage OA of the knee is not uncommon but both sarcopenic and non-sarcopenic OA patients could reach significant clinical and functional improvement after TKA. Further studies with increased sample size and different ethnicities can help ascertain a beneficial role of TKA on sarcopenic OA subjects.

Background

Sarcopenia, defined as age-related decline in muscle mass and strength, is a common condition in the aging population resulting in significant functional impairment and inactivity [1-3]. The prevalence of sarcopenia increases with age, reaching an astounding 50% among the population aged 75 or above in the United States [4]. Sarcopenia is often associated with frailty, falls, fractures and disability in this susceptible population [5-7]. Furthermore, the disease is a strong predictive risk factor for mortality and morbidity among the older patients in the nursing home [8].

Notably, sarcopenia often accompanies osteoarthritis (OA). However, the relationship between sarcopenia and OA is still unclear and no strong consensus can be reached [9, 10]. Sarcopenia and OA have been postulated to be a co-existing condition [11, 12], sarcopenia as a risk factor for OA progression [13] and vice versa with risk of sarcopenia

increased in patients with OA [14]. Cross-sectional studies revealed that OA in the knee is associated with declines in muscle mass and strength in their lower limbs as they adapt a sedentary lifestyle and inactivity to avoid knee joint pain and stiffness [15-18]. In turn the subsequent reduction in energy expenditure, together with ageing-related gains in adipose tissue lead to these patients developed overweight or even obesity. This increased load would further exacerbate their knee OA progression, and it is the combination of these factors that have been regarded to create and perpetuate a vicious cycle between obesity, sarcopenia and osteoarthritis[19, 20].

Patients with end-stage OA of the knee will eventually pursue total knee arthroplasty (TKA) as the only viable option. TKA has been proven to relieve pain and regain patients' mobility. It has been widely accepted that TKA will greatly increase social, physical and quality of life [21-24]. Despite common coprevalence of sarcopenia and OA, reports on the impact of sarcopenia on end-stage OA patients undergoing TKA are limited to two recent retrospective case-control studies suggesting patients with sarcopenia undergoing primary TKA have greater in-hospital length of stay, increased odds of 90-day medical complications, falls, lower extremity fractures, prothetic joint infection and reoperations[25, 26]. Frailty, a closely associated condition with sarcopenia, has also been linked to higher rate of mortality, post-operative admission to intensive care unit, discharge to institutional care and re-admission in a recent population-based study of patients undergoing TKA[27]. On the other hand, whether TKA can benefit sarcopenic OA subjects as in non-sarcopenic OA subjects were previously unexplored. It is not known after TKA improving knee symptoms in sarcopenic OA subjects can they attend significant improvement in muscle strength, muscle mass and gait speed which are the main domains that define sarcopenia. It may be possible that after TKA sarcopenic patients can participate in more activities that improve their muscle strength and gait speed as they are now free from knee pain. A longitudinal study that examines and observes changes in sarcopenic features after TKA over time can bridge the knowledge gap in this aspect and can provide insight into how to best manage patients with concomitant OA and sarcopenia.

This study aims to examine the status of sarcopenia in individuals with symptomatic end-stage OA of the knee and the subsequent interaction between sarcopenia and TKA which was employed as definitive treatment of OA. It is hypothesized that after TKA sarcopenic patients can gain improvement in their knee symptoms and functioning as in non-sarcopenic patients.

Methods

This study was conducted in compliance with the Declaration of Helsinki and was approved by The Joint Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee (Ethics approval number: 2015.539). Study registration was made with the US ClinicalTrials.gov (NCT03579329).

This prospective study was conducted at the Prince of Wales Hospital, Hong Kong from 1st November 2015 to 30th May 2018. Consecutive patients visiting the Orthopaedics Specialist Outpatient Clinic with symptomatic end-stage OA of the knee referred and opted for TKA as treatment are invited to participate in the study. Radiographic severity of knee OA was assessed and documented based on the Kellgren and Lawrence classification [28]. Clinical diagnosis of knee OA was based on medical history and clinical examination of knee joints. Clinical diagnosis of sarcopenia was examined using the Asian Working Group for Sarcopenia (AWGS) algorithm after they are recruited into the study[29].

Sample Size

The estimated study sample size is 50. Sample size was calculated using G*Power 3.1.9. This calculation was based upon DXA parameter being an indicator of sarcopenia[30]. As there are no similar previous studies, the sample size was calculated based on our pilot data of the present study comparing the DXA data measured at recruitment and after 12 months. Results showed DXA difference increased from the mean values of 5.84 to 6.02 after 12 months. Accounting for the 3.1% increase with the significant levels at 0.05 and power of 0.8 yielded a sample size of 45. Expecting a 10% withdrawal rate, a total of 50 subjects were required. Instead, researchers were able to finalise the recruitment of 58 end-stage OA knee patients upon their fulfilment of study prerequisites for this research.

Eligibility Criteria

The inclusion criteria are: (1) aged over 50 with end-stage knee OA; (2) scheduled for TKA; (3) agreed to given written consent and be able to comply with study assessments. Exclusion criteria include (1) history of connective tissue disorders or myositis condition; (2) previous cases of alcoholism or drug abuse; (3) breastfeeding or pregnant women; (4) presence of serious pathologies with steroid-based systematic therapy in progress or got interrupted of less than 1 month, or significant hematological disease; and (5) presence of significant cognitive impairment. The status of sarcopenia was examined by AWGS algorithm after participant enrollment into the study.

Physical Measurements

Patients demographic were recorded upon enrollment. Bodyweight and height were measured using a standard stadiometer and their Body Mass Index (BMI) was calculated (bodyweight in kg/[height in m]^2). Body composition at baseline and follow-ups were measured using dual-energy X-ray absorptiometry (DXA) (Horizon, Hologic, Bedford, MA). Total appendicular skeletal muscle mass (ASM) was calculated by the sum of lean mass measured in the 4 limbs, with the operator adjusting the cut lines of the limbs as described by Heymsfield *et al.*[31] Knee flexion/extension muscle strength were measured by instructing the patient to perform an active knee flexion/extension movement in a sitting position with both feet free from ground, and the hip flexed at 90 degree and knee joint in mid-flexion range. The optimal isometric force of the knee flexion/extension movement is measured by the dynamometer attached at the malleoli level with a strap. The measurements were taken at maximum force for three times. Grip strength was measured as the average of 3 repeated grip measurement on a dynamometer using the dominant hand. The six-meter gait speed test was used to measure gait speed by using the best time in seconds to finish a 6-m walk along a straight line using usual walking speed and the average value was used for analysis.

Definition of Sarcopenia

Sarcopenia was defined according to the Asian Working Group for Sarcopenia (AWGS) algorithm[29]. A person who has low muscle mass, low muscle strength, and/or low physical performance was categorized as having sarcopenia. Low muscle mass was defined as height-adjusted muscle mass by DXA <7.0 kg/m^2 for men and <5.4 kg/m^2 for women; low muscle strength was defined as grip strength <28 kg for men and <18 kg for women; and low physical performance as gait speed <1.0 m/s for both men and women.

Outcomes

Assessments were consecutively conducted within one month before TKA (baseline), 6 months (post-treatment), and 12 months postoperatively. Primary outcomes were regularly examined via handgrip (handgrip dynamometer at upper extremity strength), lower limb muscle strength in terms of knee joints flexion/extension and 6-meter gait

speed test at lower extremity functions. DXA measurement values were used to produce the Lean Mass Index (LMI) which is defined as the ratio of total lean mass (soft tissue only, excluding bone) to height-squared and the Appendage Lean Mass Index (ALMI) which is defined as the ratio of lean mass on limbs to height-squared.

Secondary outcomes were measured by Quality of Life (QOL) measurements in psychological and physical health. Pain, stiffness and physical functions of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) indicated scores ranging from zero to 100, with higher scores representing greater associable disability functions. Medical Outcomes Study Short Form 12 Health Survey Version 2 (SF-12v2) were administered to approximate the general health status in subjects as means to compute a Physical and Mental Health Composite Score (PCS & MCS) that range from a scale of zero to 100, indicated by the higher the score the better level of health. International Physical Activity Questionnaire (IPAQ) instructed an internationally comparable record of health-related physical activity, used to monitor changes of the amount or types of exercise performance level over the research period. Physical activity levels in terms of IPAQ were categorised as "low", "moderate" and "high" and the categorization followed the standard criteria[32, 33]. The contraposition of SF-12v2 and IPAQ indexes across research timelines allowed meaningful interpretation of bodily and psychological functional fluctuation over the effect of TKA on sarcopenia symptom.

Statistical analysis

Demographic statistics on age, sex, BMI, and length of hospital stay were reported in terms of mean ± SD or frequencies where appropriate (Table 1). Comparisons of ALMI and LMI against patients with or without sarcopenia were carried out both cross-sectionally (between patients with sarcopenia or not) and longitudinally (among the 3-time points (baseline, 6 months and 12 months)) correspondingly. Longitudinal comparisons of mean values of PCS and MCS in SF12v2, WOMAC domain scores, IPAQ findings in terms of low, moderate, and high activities, knee flexion/extension strength, as well as handgrip scores and 6-meter gait speed were made. To control the possible confounders, further longitudinal comparisons were performed by controlling sex, age, and BMI using one-way ANOVA. A two-sided p-value ≤ 0.05 was considered statistically significant. All statistical analyses were carried out using IBM SPSS Version 26.0 (Armonk, NY: IBM Corp).

Results

Fifty-eight patients were recruited with 12 male and 46 female. Nineteen (32.8%) patients had sarcopenia at baseline. The mean age of sarcopenic subjects and non-sarcopenic subjects were comparable (67.89±7.07 vs 67.92±6.85; p=0.99) and sarcopenic subjects have lower BMI (25.64±2.64 vs 28.57±4.04; p=0.01). Background medical comorbidities were comparable between the two groups. Patients with sarcopenia stayed slightly longer in the hospital after surgery despite not statistically different from without sarcopenia (8.11 vs. 7.39 days, p=0.61). The demographic characteristics of the patient are summarized in Table 1.

Primary outcomes (Muscle Mass & strength)

After undergoing total knee arthroplasties, there was a statistically significant improvement in walking speed in both sarcopenic and non-sarcopenic patients as evident by reduced time in the six-meter gait speed test (10.24±5.35 (Baseline) to 7.69±2.68 (12 months), p<0.01) (Table 2) (Supplemental Figure 1). There were statistically significant improvements in operated knee extension muscle strength (12.56 vs. 15.53, p<0.01) and flexion muscle strength (5.34 vs. 6.53, p=0.03) in both sarcopenic and non-sarcopenic patients after TKA. These were accompanied by improvement trend in muscle mass in both sarcopenic and non-sarcopenic patients at 12 months (The Lean Mass

Index (LMI) in sarcopenic: 12.93±1.27 (baseline) to 13.27±1.3 (12 months), p=0.14; LMI in non-sarcopenic: 14.96±1.83 (baseline) to 15.42±2.01 (12 months), p=0.06) (Table 3). After controlling for possible confounders, it was found that sarcopenic female that were overweight or obese had statistically significant improvement in both ALMI ([Age≤75, female, overweight or obese]: 4.89 (Baseline) vs. 4.96 (6 months) vs. 5.10 (12 months); p=0.04) and [Age>75, female, overweight or obese]: 4.47 vs. 4.60 vs. 4.79; p=0.05) and LMI ([Age≤75, female, overweight or obese]: 12.30 vs. 12.45 vs. 12.86; p=0.04 and [Age>75, female, overweight or obese]: 11.78 vs. 11.86 vs. 12.26; p=0.04) after total knee arthroplasties (Table 4) (Supplemental Figure 2). Nevertheless, despite the increase in muscle mass after TKA, both the ALMI and LMI in sarcopenic subjects remained lower than non-sarcopenic subjects at twelve months with statistical significances ([ALMI] At baseline: 5.26 (Sarcopenia = Yes) vs.6.11 (Sarcopenia = No); p<0.01; 6 months: 5.22 vs. 6.15; p=0.02; 12 months: 5.38 vs. 6.28; p<0.01)([LMI] At baseline: 13.10 (Sarcopenia = Yes) vs.14.96 (Sarcopenia = No); p<0.01; 6 months: 12.99 vs. 15.06; p=0.01; 12 months: 13.39 vs. 15.42; p<0.01) (Table 5). There was no change in handgrip power before and after TKA and subsequent follow-up (19.31 (Baseline) vs. 18.98 (6 months) vs. 19.36 (12 months); p=0.97) (Table 2).

Secondary outcome measures (Quality of Life) (Table 2)

Patient outcome measures were kept improving in terms of WOMAC Pain domain (Baseline vs. 6 months vs. 12 months = 8.67 vs. 4.32 vs. 3.73, p<0.01), Stiffness domain (3.48 vs. 2.03 vs. 1.77, p<0.01), and Function domain (30.12 vs. 14.26 vs. 11.69, p<0.01). Physical component score of SF12v2 also echoed the improvement (33.06 vs. 38.96 vs. 40.67, p<0.01). In conjunction with this trend, percentage distributions of IPAQ ratings showed increased engagement of high-intensity activities (Supplemental Figure 3).

Adverse events

No adverse event was noted during this study.

Discussion

Our study illustrates a high prevalence of sarcopenia among patients with end-stage OA of the knee. There were 58 patients entered at baseline, of which 19 (32.8%) had sarcopenia and 39 (67.2%) were not. The prevalence of sarcopenia in Asia ranged from 6.7% to 18.6% in older men and 0.1% to 23.6% in older women according to various reports from Japan, Taiwan, Hong Kong and Korean[34-37]. However, it has also been found that the prevalence of sarcopenia among community-dwelling elderly with OA is near three times that of those without OA and this possibly explains the relatively high prevalence of sarcopenia among our OA subjects[38].

This study demonstrated that total knee arthroplasties can benefit patients with severe knee OA with or without co-existing sarcopenia by improving knee function and symptoms, in turn enhancing their lower limb muscle strength, gait speed and potentially lean muscle mass. It is important to note that deficit in gait speed, muscle strength and lean muscle mass are the core components that defined sarcopenia. According to the latest review in Lancet on sarcopenia, physical activity is regarded as the primary treatment of sarcopenia while there is currently no specific drugs approved for the treatment of sarcopenia [39]. Our study illustrates the importance of identifying sarcopenic patients with concomitant joint disease and managed accordingly to facilitate them having physical activity, which may in turn benefit their concomitant sarcopenia. At the end of this study, five sarcopenic patients at baseline turned non-sarcopenic, leading to a total of 44 patients without sarcopenia (75.9%). However, our results also showed that knee arthroplasty alone cannot allow sarcopenic subjects to pick up the overall difference in average lean muscle mass compared to non-sarcopenic subjects. This highlights the importance of managing sarcopenia

through a multimodal approach, for example, a combination of high protein diet, knee arthroplasties, and followed by supervised exercise program which by then should be more effective as the physical limitation by knee osteoarthritis has been alleviated. In our study, the patients only received standard physiotherapy designed for rehabilitation of knee arthroplasty surgery to improve knee range and walking ability but does not target building skeletal muscle strength and mass as in those resistance exercise program for sarcopenia. Having said that, some of these OA patients were elderly with low motivation and content with pain-free knees without further interest to participate in further sarcopenia muscle strengthening exercise. As such some passive physical intervention or "exercise mimetics" like neuromuscular electrical stimulation or whole-body vibration can be considered for those elderly.[40] In fact, whole-body vibration has been shown to increase knee extensor strength and decrease lower leg swelling after TKA and thus worth further investigation on their combined effect on sarcopenia[41].

To our best knowledge, our study is the first one to observe the status of sarcopenia after TKA longutidinally, monitoring the change in muscle strength, muscle mass and gait speed over time. Previous studies have focused on pre-operative sarcopenia as a risk factor for poor surgical outcome. For example, sarcopenia has been identified as risk factors for morbidity and mortality in colorectal surgery and gastric cancer surgery, and also as risk factor for prosthetic infection after joint arthroplasty [26, 42, 43]. In our study, no increase in infection rate nor other complications were found, nevertheless, the timeframe for late infection and late complications are beyond this study period. One important difference between the current study and the previous researches on sarcopenia with surgery is that those surgeries mainly induce a catabolic status in the patients while knee arthroplasty induces catabolism in early phase followed by anabolism due to patient regaining their mobility and ability to exercise. This phenomenon may potentially explain the improvement of lean mass in overweight or obese sarcopenic female in our study as they lost fat and weight during the initial catabolism after arthroplasty and built up muscle, made possible by better walking ability and less bodyweight hindering movement, during their subsequent rehabilitation[19, 38, 44]. However, the finding is limited by the small scale of our study and further studies with larger sample sizes are warranted to validate this relationship.

There are certain limitations in our study. Firstly, all patients receive standard physiotherapy in the early phase for post-op rehabilitation. Afterwards, we did not restrict or prescribe further exercise to patients and each of them may engage in variable degrees of exercise. This could contribute to variable improvement in muscle mass among our patients. Nevertheless, we found in general they engaged in more exercise as reflected by improvement in WOMAC function domain, physical component score of SF12v2, and higher percentage distributions of IPAQ ratings of high-intensity activities (Supplemental Figure 3). Similarly, although we encourage our patients to have high protein intake according to dietitian advice, we could not control the exact patients' diets at home and those having a relatively higher protein diet may have better muscle mass building than their counterpart[39]. Besides, as there were no previous studies looking into the same topic, the sample size in this study was based on our pilot data only and was small. A larger replicating study may help confirm the change in muscle mass over time, which we showed only a trend of improvement without statistical significance in the overall sarcopenic group. Another limitation is that our study examine sarcopenia using the Asian Working Group for Sarcopenia (AWGS) algorithm and therefore the results may not be applicable to other ethnicities, for example to Caucasians in which sarcopenia is diagnosed by the consensus definition of the European Working Group on Sarcopenia in Older People (EWGSOP2)[45]. Future population-based studies on other ethnicities with different lifestyle may provide a more comprehensive understanding on the interrelationship between TKA and sarcopenia.

Conclusions

To conclude, our study showed that sarcopenia among patients with end-stage OA of the knee is not uncommon. Total knee arthroplasty can provide significant improvement in pain, stiffness and function in sarcopenic OA patients. Domains of sarcopenia like muscle strength and gait speed showed improvement after TKA. Further studies with increased sample size and different ethnicities can help ascertain the role of TKA on sarcopenic OA subjects.

Declarations

Ethics approval and consent to participate:

- Ethical approval was obtained from the ethics review board of the Joint NTEC/CUHK Ethics Committee (Research Ethics Committee approval number: 539).

Consent for publication:

- Written informed consent was obtained from every participant.

Availability of data and materials:

- The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:

- The authors declare that they have no competing interests.

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Author's contributions

- Kevin Ki-Wai Ho and Lawrence Chun-Man Lau designed the research, collected and assembled the data, and wrote the paper. Wai-Wang Chau analysed and interpreted the data and contributed to the writing of the paper. Queena Poon collected and assembled the data. Kwong-Yin Chung and Ronald Man-Yeung Wong contributed to the writing of the paper. All authors took part in the writing and final editing of the manuscript. All authors have been given a copy of the manuscript, all have approved the final version of the manuscript, and all are prepared to take public responsibility for the work and share responsibility and accountability for the results.

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Tables

Table 1. Demographic characteristics of patients with or without sarcopenia (N=58)

Demographic variables	Sarcopenia		P value
	Yes (N=19)	No (N=39)	
Age			
≤75	16 (84.2)	33 (84.6)	1.00
>75	3 (15.8)	6 (15.4)	
Sex			
Male	5 (26.3)	7 (17.9)	0.50
Female	14 (73.7)	32 (82.1)	
BMI			
Normal	9 (47.4)	7 (17.9)	0.03
Overweight or obese	10 (52.6)	32 (82.1)	
Smoking			
Yes	0	0	-
No	19 (100.0)	39 (100.0)	
Drinking Behavior			
Yes	0	0	-
No	19 (100.0)	39 (100.0)	
Diabetes Mellitus			
Yes	5 (26.3)	18 (46.2)	0.17
No	14 (73.7)	21 (53.8)	
Hypertension			
Yes	12 (63.2)	28 (71.8)	0.55
No	7 (36.8)	11 (28.2)	
Hyperlipidemia			
Yes	3 (15.8)	15 (38.5)	0.13

No	16 (84.2)	24 (61.5)	
Neurological disease			
Yes	0	3 (7.7)	0.54
No	19 (100.0)	36 (92.3)	
Renal disease			
Yes	2 (10.5)	1 (2.6)	0.25
No	17 (89.5)	38 (97.4)	
Cardiac disease			
Yes	3 (15.8)	4 (10.3)	0.67
No	16 (84.2)	35 (89.7)	
Respiratory disease			
Yes	0	3 (7.7)	0.54
No	19 (100.0)	36 (92.3)	
Gastrointestinal disease			
Yes	0	1 (2.6)	1.00
No	19 (100.0)	38 (97.4)	
Medication with muscle wasting consequence			
Yes	0	0	-
No	19 (100.0)	39 (100.0)	

Table 2. Longitudinal comparisons of SF12v2, WOMAC, IPAQ, and Functional Assessments of all patients

Questionnaires and Functional Assessments	Time point			P value
	Baseline	6 months	12 months	
SF12v2				
PCS	33.06±8.55	38.96±8.01	40.67±7.93	<0.01
MCS	45.87±9.70	47.04±10.53	48.50±10.19	0.46
WOMAC				
Total	42.27±15.98	20.65±15.24	16.65±18.13	<0.01
Pain	8.67±3.51	4.32±3.20	3.73±4.62	<0.01
Stiffness	3.48±1.81	2.03±1.70	1.77±2.07	<0.01
Function	30.12±11.96	14.26±11.43	11.69±12.86	<0.01
Percentage	44.03±16.64	21.51±15.87	17.35±18.88	<0.01
IPAQ				
Low	11 (21.6)	4 (12.1)	4 (9.5)	0.24
Moderate	18 (35.3)	18 (54.5)	17 (40.5)	
High	22 (43.1)	11 (33.3)	21 (50.0)	
Knee flexion/extension muscle strength				
Operated knee extension	12.56±6.23	10.80±4.99	15.53±7.98	<0.01
Operated knee flexion	5.34±2.92	4.61±2.49	6.53±3.85	0.03
Non-operated knee extension	14.19±7.61	14.07±7.80	15.18±8.36	0.79
Non-operated knee flexion	5.55±3.13	5.49±2.48	6.74±3.94	0.15
Handgrip muscle strength	19.31±5.92	18.98±6.37	19.36±7.66	0.97
Six-meter gait speed test	10.24±5.35	7.56±2.14	7.69±2.68	<0.01

PCS: Physical component score; MCS: mental component score; IPAQ: International Physical Activity Questionnaires

Table 3. Longitudinal comparisons of Appendage Lean Mass Index and Lean Mass Index in patients with or without sarcopenia

DXA	Sarcopenia		Time point		P value
		Baseline	6 months	12 months	
ALMI	Yes	5.26±0.82	5.22±0.81	5.38±0.85	0.09
LMI		13.10±1.44	12.99±1.21	13.39±1.38	0.14
ALMI	No	6.11±0.89	6.15±1.01	6.28±1.03	0.07
LMI		14.96±1.83	15.06±1.97	15.42±2.01	0.06

Appendage Lean Mass Index (ALMI): Appendage lean mass/height^2;: Lean Mass Index (LMI): total lean mass/height^2

Table 4. Longitudinal comparisons of Appendage Lean Mass Index and Lean Mass Index in patients with and without sarcopenia

Sarcopenia	Sex	Age	BMI	DXA variables	Time points			P value
					Baseline	6 months	12 months	
Yes	Male	≤75	Normal	ALMI	6.34±0.35	6.56±0.29	6.37±0.34	0.44
			Overweight or obese	ALMI	6.03±1.46	6.51±1.67	6.79±0.21	0.40
		>75	Normal	ALMI	5.07±0.09	5.38±0.11	5.28±0.15	0.42
			Overweight or obese	ALMI	5.35±0.47	5.23±0.17	5.21±0.14	0.48
		≤75	Normal	LMI	14.45±0.64	14.60±0.35	14.65±0.07	0.45
			Overweight or obese	LMI	14.50±2.52	14.90±1.58	15.50±0.57	0.44
		>75	Normal	LMI	12.22±1.19	12.34±1.69	12.54±0.68	0.46
			Overweight or obese	LMI	13.39±0.87	14.09±0.62	13.76±0.95	0.45
	Female	≤75	Normal	ALMI	5.17±0.17	5.28±0.52	5.30±0.15	0.31
			Overweight or obese	ALMI	4.89±0.15	4.96±0.15	5.10±0.38	0.04*
		>75	Normal	ALMI	5.05±0.07	5.12±0.10	5.18±0.10	0.34
			Overweight or obese	ALMI	4.47±0.43	4.60±0.41	4.79±0.52	0.05*
		≤75	Normal	LMI	13.50±0.28	13.90±0.42	14.10±0.28	0.34
			Overweight or obese	LMI	12.30±1.01	12.45±1.35	12.86±0.21	0.04*
		>75	Normal	LMI	13.30±0.27	13.70±0.26	13.90±0.72	0.36
			Overweight or obese	LMI	11.78±0.77	11.86±1.13	12.26±0.88	0.04*
No	Male	≤75	Normal	ALMI	6.44±0.57	6.21±0.22	6.54±0.43	0.39
			Overweight or obese	ALMI	7.69±0.55	8.04±0.64	7.95±0.86	0.39
		>75	Normal	ALMI	7.37±0.37	7.54±0.69	7.46±0.12	0.38

			Overweight or obese	ALMI	7.89±0.50	8.21±0.66	7.94±0.74	0.42
		≤75	Normal	LMI	14.70±1.44	14.25±0.49	14.70±0.85	0.45
			Overweight or obese	LMI	17.80±1.29	18.83±1.05	18.45±1.93	0.33
		>75	Normal	LMI	16.40±1.59	16.90±0.38	16.65±0.35	0.31
			Overweight or obese	LMI	17.98±1.41	18.54±1.02	18.39±1.84	0.34
	Female	≤75	Normal	ALMI	4.85±0.25	4.74±0.23	4.72±0.22	0.41
			Overweight or obese	ALMI	6.05±0.53	5.92±0.66	6.06±0.56	0.36
		>75	Normal	ALMI	4.59±0.05	4.28±0.14	4.44±0.22	0.49
			Overweight or obese	ALMI	5.90±0.34	5.95±0.57	6.27±0.53	0.27
		≤75	Normal	LMI	12.17±0.51	12.00±0.28	12.25±0.49	0.43
			Overweight or obese	LMI	14.90±1.10	14.88±1.38	15.11±1.30	0.40
		>75	Normal	LMI	12.00±1.34	11.40±1.36	11.70±0.42	0.48
			Overweight or obese	LMI	14.80±1.70	14.15±0.92	15.25±0.99	0.34

* Statistical significance using ANOVA

Appendage Lean Mass Index (ALMI): Appendage lean mass/Height^2;: Lean Mass Index (LMI): Total lean mass/Height^2

Table 5. Cross-sectional comparisons of Appendage Lean Mass Index and Lean Mass Index between patients with and without sarcopenia in the 3 time points

DXA scores	Time point	Sarcopenia		P value
		Yes	No	
ALMI	Baseline	5.26±0.82	6.11±0.89	<0.01
	6 months	5.22±0.81	6.15±1.01	0.02
	12 months	5.38±0.85	6.28±1.03	<0.01
LMI	Baseline	13.10±1.44	14.96±1.83	<0.01
	6 months	12.99±1.21	15.06±1.97	0.01
	12 months	13.39±1.38	15.42±2.01	<0.01

Appendage Lean Mass Index (ALMI): Appendage lean mass/height^2;: Lean Mass Index (LMI): total lean mass/height^2

Figures

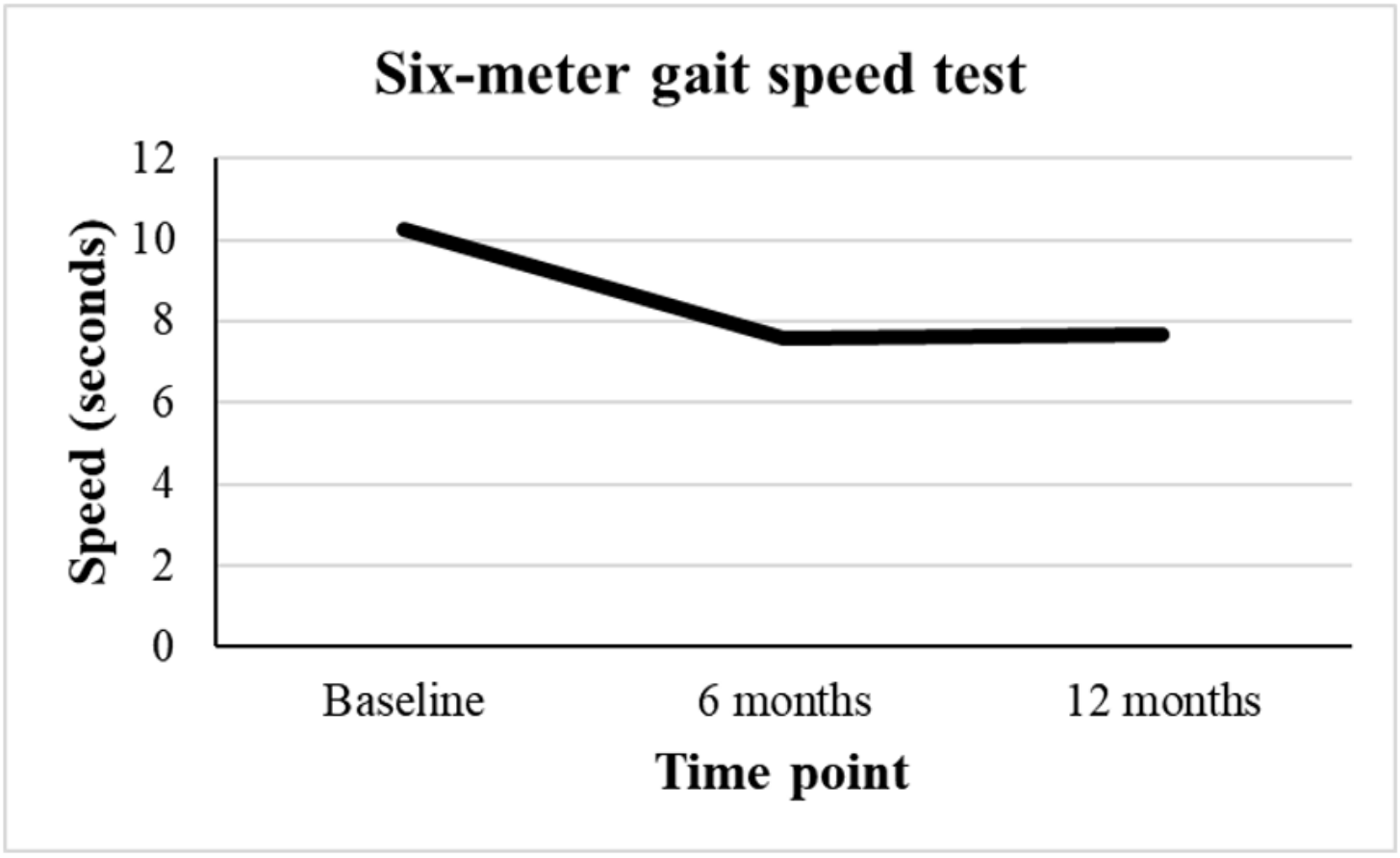
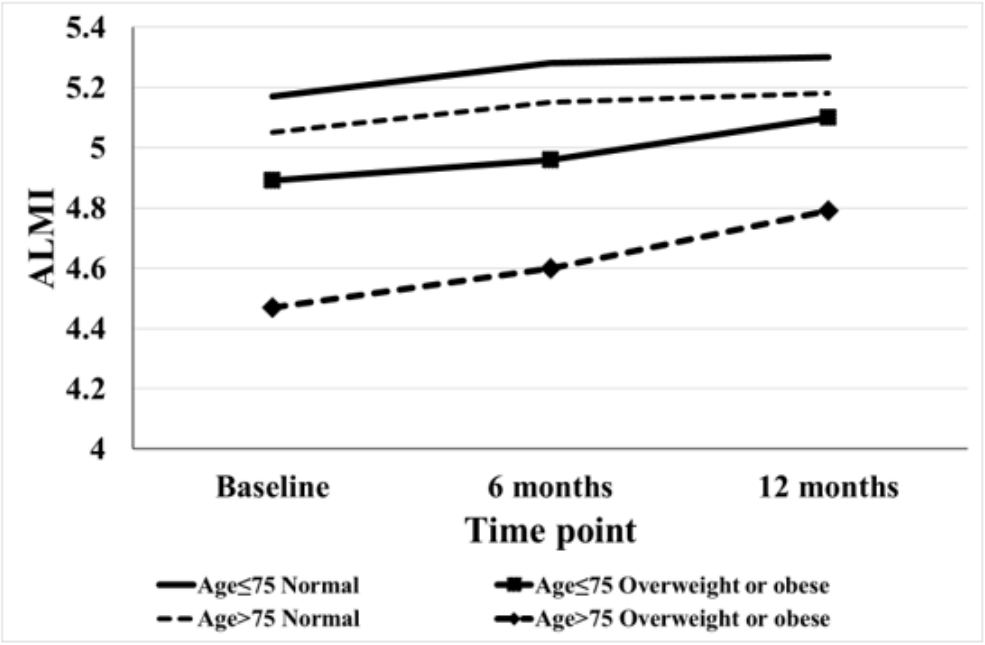


Figure 1

Muscle Function changes after TKA: Six-meter gait speed test across the time points



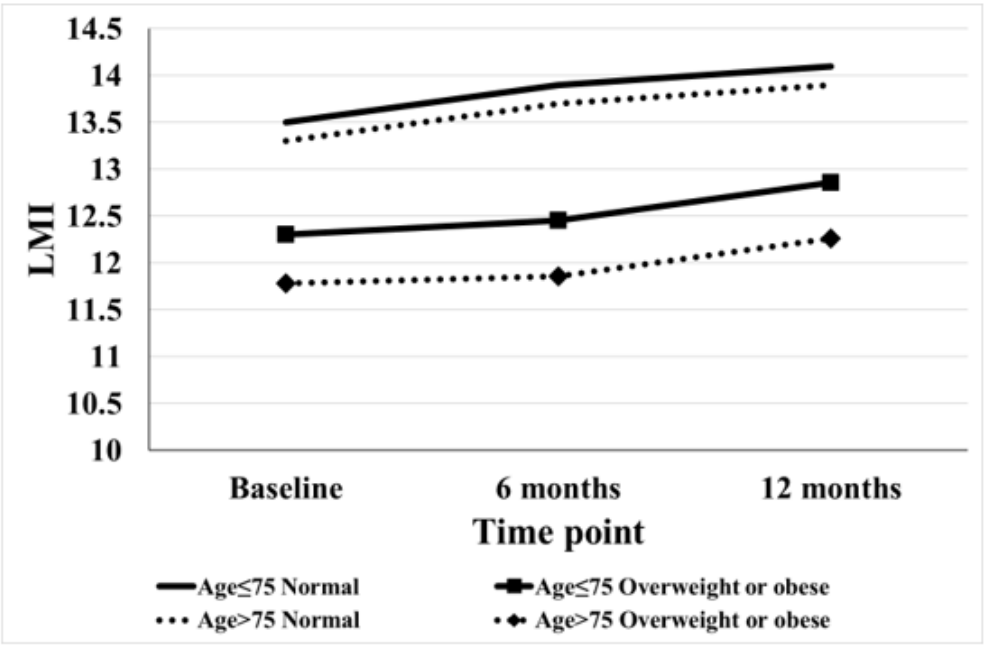
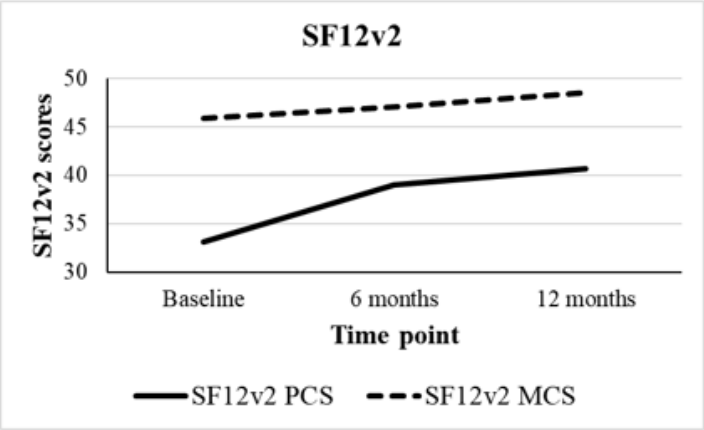
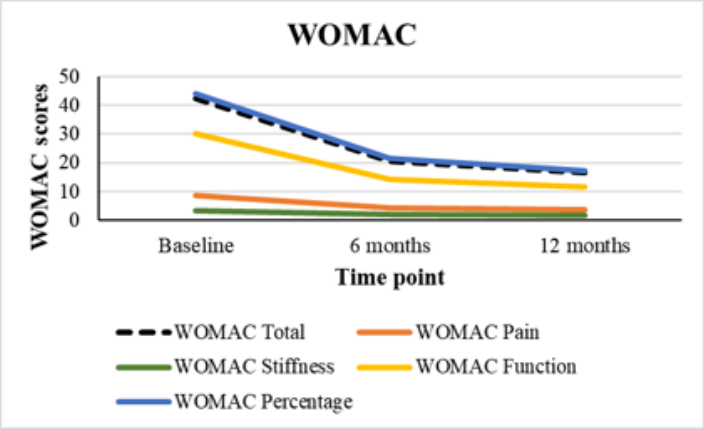


Figure 2

Muscle Mass changes after TKA: Longitudinal changes of Appendage Lean Mass Index (ALMI) and Lean Mass Index (LMI) scores in sarcopenia patients of different age groups and BMI categories





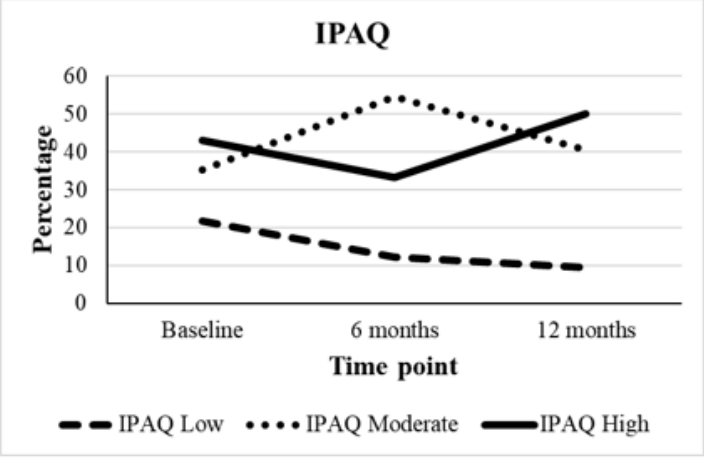


Figure 3

Quality of Life changes after TKA: Longitudinal changes of SF12v2 , WOMAC, and IPAQ showing a gradual improvement in physical function and decreased pain after total knee arthroplasty