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Original Research

Prevalence of Sarcopenia and Sarcopenic Obesity in an Academic Total Joint Arthroplasty Practice

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ABSTRACT

Background: Body mass index (BMI) is routinely used for preoperative risk stratification; however, it does not provide a detailed assessment of body composition and intentional weight loss alone may not decrease complications. Sarcopenia—a disorder involving low muscle mass, quality, or performance—has been associated with an increased risk for postoperative complications and is treatable through nutritional supplementation or resistance training. It, counterintuitively, may occur with obesity as "sarcopenic obesity"; however, the prevalence is not widely known. The purpose of this study was to assess the prevalence of sarcopenia and sarcopenic obesity.

Material and methods: Patients underwent body composition assessment using multifrequency bioimpedance testing (InBody 770, InBody USA, California). They were classified as sarcopenic based on the appendicular skeletal muscle index and obese by percent body fat. Body composition parameters were compared between obesity or sarcopenia groups and traditional BMI-based obesity definitions.

Results: A total of 219 patients underwent body composition assessment. The mean age was 62.1 years, BMI was 34.3 kg/m^2, and 53.8% were female. Fifty-seven (26.0%) patients were not obese or sarcopenic, 130 (59.4%) were obese not sarcopenic, 18 (8.2%) were sarcopenic nonobese, and 14 (6.4%) were sarcopenic obese. There was heterogeneity in body composition between groups. Sarcopenic patients were older than those without sarcopenia. Skeletal muscle mass, body fat mass, and appendicular skeletal muscle index increased with increasing BMI.

Conclusion: Sarcopenia and sarcopenic obesity were found in nearly 15% of patients. Measures of muscle quantity increased with higher BMI may influence the prevalence of sarcopenia in the morbidly obese, and these patients may require specialized criteria accounting for increased body mass.

Introduction

The global prevalence of obesity continues to rise, and the proportion of obese patients seeking total joint arthroplasty (TJA) has disproportionally increased [1–4]. Obesity, and particularly morbid obesity, is known to incur elevated risk for perioperative complications, including periprosthetic joint infection (PJI), aseptic loosening, and all-cause mortality following TJA [5–11]. Obesity is largely considered to be a modifiable, patient-specific risk factor, and the current paradigm is risk stratification through assessment of body mass index (BMI) [12]. For patients deemed to be at unacceptably high risk secondary to obesity, surgeons will often deny TJA and prescribe weight loss, with a goal BMI of <40 kg/m^2 [13]. Recently, the effectiveness of withholding surgery to incentivize weight loss in the morbidly obese has come under question, as nearly half of patients who are prescribed weight loss do not return for a second office visit, and of the half that do, less than half eventually undergo TJA, at a mean BMI exceeding 40 kg/m^2 [14–16]. Furthermore, recent investigation has paradoxically associated rapid weight loss preceding elective TJA with an increased risk for complications [17,18].

While BMI is widely utilized to monitor weight loss and to quantify obesity, it has several limitations including inability to quantify fat, fat distribution, and/or muscle mass or account for differences related to gender or body type [19]. Given the

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Table 1
Patient demographics and body composition measurements.

Demographics	All (n = 219)	Female (n = 118)	Male (n = 101)
Age, mean (SD)	62.1 (11.0)	61.9 (11.0)	62.3 (10.9)
% Female	53.8%	100.0%	0.0%
Height, cm (SD)	170.6 (10.2)	163.8 (7.1)	178.6 (6.9)
Range	144.8-195.6	144.8-180.3	161.0-195.6
Weight, kg (SD)	100.3 (28.2)	92.2 (27.6)	109.6 (26.1)
Range	41.1-184.1	43.1-173.5	64.0-184.1
BMI, kg/m^2 (SD)	34.3 (8.7)	34.2 (9.5)	34.3 (7.6)
Range	17.5-63.7	17.5-63.7	21.0-55.0
BFM, kg (SD)	41.0 (19.7)	42.5 (19.9)	39.2 (19.3)
Range	8.5-98.7	9.3-98.7	8.5-88.8
PBF (SD)	39.4% (10.8)	43.8% (9.6)	34.2% (9.8)
Range	9.3-58.3	18.7-58.3	9.3-53.8
SMM, kg (SD)	32.6 (8.6)	26.9 (5.2)	39.2 (6.8)
Range	16.0-57.4	16.0-43.5	20.3-57.4
LBM, kg (SD)	59.3 (14.5)	49.7 (8.9)	70.4 (11.5)
Range	31.2-100.9	31.2-76.4	39.4-100.9
ASMI, kg/m^2 (SD)	8.5 (1.6)	7.6 (1.3)	9.5 (1.2)
Range	4.5-12.3	4.5-11.5	6.1-12.3
Phase angle,- (SD)	4.8 (0.9)	4.4 (0.8)	5.2 (0.9)
Range	2.7-7.6	2.7-6.6	3.2-7.6

limitations of a metric using a height-to-weight ratio, BMI alone is unable to identify if there is another condition—independent of body weight—that may be related to risk of complications following TJA. From the Greek "sarx" (flesh) and "penia" (aging), sarcopenia was originally described in 1989 as an age-related disorder of decreased muscle mass, and multiple definitions and diagnostic criteria have subsequentially been proposed [20–22]. Sarcopenia has garnered attention in other surgical specialties for its association with postoperative complications and has gained attention in orthopaedics and lower extremity arthritis [23–26]. Recently, sarcopenia has been linked to an increased risk for PJI, longer length of stay, and increased overall complications following TJA [27,28]. Counterintuitively, sarcopenia may occur concurrently with situations of obesity and age-related increases in adiposity. Despite the recent understanding of unique risks associated with sarcopenic obesity, there is evidence that this condition is both underdiagnosed and prevalence is expanding owing to an aging United States population with a concurrent obesity epidemic [29–31]. Sarcopenia may also occur within the bounds of what is considered to be a "normal" BMI, and high-risk patients may go undetected using traditional preoperative risk assessment [32]. Importantly, interventions, such as nutritional supplementation with essential amino acids and light resistance training with exercise bands, have demonstrated success in treating sarcopenia and limiting muscle wasting [33–37].

The prevalence of sarcopenia and sarcopenic obesity is not known in patients seeking TJA and may be particularly relevant due to an increasing obese population seeking arthritis care and age-related increases in adiposity and decreases in muscle mass [29]. A recent study using the SARC-F, an activity-based screening questionnaire, found over two-thirds of patients seeking care for osteoarthritis were at risk for having sarcopenia [38]. The purpose of this study was to assess the prevalence of sarcopenia and sarcopenic obesity among patients presenting to an academic TJA practice and report on body composition parameters within these groups.

Material and methods

This study was reviewed and approved by our institutional review board. Patients presenting to our institution's adult reconstruction clinic were identified. Eligible patients were ≥18 years of age and underwent body composition assessment using bioimpedance (BIA) testing between February 2020 and April 2021.

Table 2
Obesity and sarcopenic prevalence.

Demographics	No sarcopenia	Sarcopenia
All patients		
No obesity	57 (26.0%)	18 (8.2%)
Obese	130 (59.4%)	14 (6.4%)
Female		
No obesity	30 (25.4%)	11 (9.3%)
Obese	73 (61.9%)	4 (3.4%)
Male		
No obesity	27 (26.7%)	7 (6.9%)
Obese	57 (56.5%)	10 (9.9%)

Assessments were performed at all new patient visits for single surgeon's practice. This included patients seeking care of primary lower extremity osteoarthritis or an existing TJA. The first body composition assessment on record was used, as some patients did undergo multiple assessments as part of presurgical body composition optimization. Patients were excluded if they declined testing, they were unable to stand for approximately 60 seconds to complete testing, or there was a medical contraindication to BIA testing, such as the presence of a cardiac pacemaker. The InBody 770 Body Composition Analyzer (InBody USA, Cerritos, CA) was used to perform the BIA assessments. This six-frequency BIA testing device provides both comprehensive and segmental extremity quantitative assessment of body composition and body water balance parameters, including skeletal muscle mass (SMM), body fat mass (BFM), intracellular water, or extracellular water. This method for assessing body composition has been previously validated for use in obese patients [39,40]. Patient height was assessed using a wall-mounted stadiometer, and body weight was determined using the BIA device.

Patients were categorized as having sarcopenia using appendicular skeletal muscle index (ASMI) criteria of <8.5 kg/m^2 for men and <6.3 kg/m^2 for women, corresponding to 2 standard deviations (SDs) below a cohort of young, healthy adults [41]. The ASMI was selected to limit the impact of increased truncal adiposity or central muscle observed in more obese individuals. Obesity was defined as exceeding the highest 2 quantiles of age-adjusted body fat percentage (PBF) (>30.3% for men, >40.9% for women) [42,43]. Patients were assessed using both the PBF and traditional BMI-based definitions, and we found the number of patients qualifying as obese to be similar. Patients were categorized into 1 of 4 phenotypes: (1) not sarcopenic or obese, (2) obese not sarcopenic, (3) sarcopenic non-obese, (4) sarcopenic obese. Additional body composition parameters, including SMM, lean body mass (LBM), BFM, and phase angle (PA), were determined using BIA. BFM includes extremity, visceral, and subcutaneous fat. SMM represents the weight of only muscle. LBM is the sum of all body components, less fat. PA is a parameter related to the ratio of intracellular and extracellular water and cellular integrity and may have value in identifying patients with sarcopenia or lymphedema [44,45]. Given the heterogeneity in body composition among individuals within or between global regions and variability associated with aging or lifestyle factors, a single, normal value is difficult to apply to all patients, though it is established SMM decreases and BFM increases with increasing age [46].

Patient age, height, weight, sex, mean BMI, and body composition parameters were evaluated using descriptive statistics. Patients were stratified based on sex, sarcopenia, and obesity phenotypes. Additionally, patients were stratified by BMI <30, 30-<39, and ≥40 kg/m^2 to evaluate body composition using traditional definitions of obesity or morbid obesity [47].

Logistic regression was used to determine odds ratios (ORs) for sarcopenia and sarcopenic obesity based on patient factors. Differences in body composition parameters between groups were determined using analysis of variance and Chi-square test, adjusted

Table 3
Patient demographics and body composition measurements.

Variable	No sarcopenia		Sarcopenia		*P*-value
	Not obese (n = 57)	Obese (n = 130)	Not obese (n = 18)	Obese (n = 14)	
Age, mean (SD)	58.9 (11.5)	62.0 (9.7)	67.3 (14.1)	69.6 (10.4)	.272[a] .022[b] .005[c] .203[d] .059[e] .931[f]
% Female	52.6%	56.2%	61.1%	28.6%	Overall: .231 .656[a] .529[b] .106[c] .691[d] .049[e] .067[f]
Height, cm (SD) Range	172.6 (9.9) 147.3-190.5	170.5 (10.5) 144.8-195.6	167.0 (8.5) 154.9-180.3	168.3 (9.0) 154.9-182.9	0.1578
Weight, kg (SD) Range	84.3 (16.5) 53.7-118.8	114.8 (24.9) 65.5-184.1	62.7 (12.5) 43.1-82.9	78.4 (11.7) 57.7-94.1	<.001[a] .002[b] .801[c] <.001[d] <.001[e] .174[f]
BMI, kg/m^2 (SD) Range	28.0 (3.5) 21.0-35.6	39.4 (7.2) 28.7-63.7	22.3 (3.0) 17.5-26.8	27.6 (2.7) 22.8-32.1	<.001[a] .003[b] .994[c] <.001[d] <.001[e] .068[f]
BFM, kg (SD) Range	24.3 (7.4) 8.8-50.9	52.9 (16.2) 28.6-98.7	16.8 (5.2) 8.5-25.1	30.0 (4.7) 21.7-37.6	<.001[a] .163[b] .473[c] <.001[d] <.001[e] .029[f]
PBF (SD) Range	29.1% (7.5) 9.3-49.5	45.7% (7.5) 29.6-58.3	27.0 (6.8) 12.4-40.2	38.6% (5.6) 21.7-37.6	<.001[a] .706[b] <.001[c] <.001[d] .004[e] <.001[f]
SMM, kg (SD) Range	33.2 (8.7) 19.5-50.5	34.1 (8.2) 19.7-57.4	24.5 (6.3) 16.0-34.2	26.3 (6.0) 17.9-49.0	.904[a] <.001[b] .024[c] <.001[d] .004[e] .924[f]
LBM, kg (SD) Range	60.0 (14.4) 36.8-88.7	62.0 (14.0) 36.8-100.9	45.9 (10.7) 31.2-62.5	48.4 (9.9) 33.8-62.5	.792[a] .001[b] .026[c] <.001[d] .003[e] .955[f]
ASMI, kg/m^2 (SD) Range	8.2 (1.4) 6.3-11.1	9.0 (1.5) 6.4-12.3	6.5 (1.4) 4.5-8.3	7.0 (1.1) 5.4-8.4	.002[a] <.001[b] .027[c] <.001[d] <.001[e] .647[f]
Phase angle, (SD) Range	5.2 (1.1) 2.7-7.6	4.7 (0.8) 3.2-6.9	4.1 (0.7) 2.9-5.2	4.5 (1.0) 2.8-5.9	.018[a] <.001[b] .048[c] .011[d] .695[e] .543[f]

[a] No sarcopenia, not obese vs obese, no sarcopenia.
[b] No sarcopenia, not obese vs sarcopenia, not obese.
[c] No sarcopenia, not obese vs sarcopenic obese.
[d] Obese, no sarcopenia vs sarcopenia, not obese.
[e] Obese, no sarcopenia vs sarcopenic obese.
[f] Sarcopenia, not obese vs sarcopenic obese.

Table 4
Patient demographics and body composition measurements based on BMI.

Variable	BMI <30 (n = 73)	BMI 30-<40 (n = 90)	BMI ≥40 (n = 56)
Age, mean (SD)	63.7 (12.8)	62.4 (9.4)	59.6 (10.5)
% Female	56.2%	48.9%	58.9%
Height, cm (SD)	170.4 (9.6)	171.0 (10.6)	170.5 (10.4)
Range	147.3-193.0	144.8-195.6	144.8-193.0
Weight, kg (SD)	74.9 (15.1)	99.2 (14.0)	135.1 (21.2)
Range	43.1-108.5	65.5-132.5	86.1-184.1
BMI, kg/m^2 (SD)	25.5 (3.1)	33.8 (2.6)	46.4 (5.1)
Range	17.5-29.9	30-39.4	40.2-63.7
BFM, kg (SD)	22.3 (7.0)	39.4 (8.2)	67.9 (12.2)
Range	8.5-38.9	22.7-58.2	38.5-58.3
PBF (SD)	29.9% (7.7)	40.2% (8.2)	50.4% (5.5)
Range	9.3-45.5	23.2-54.2	31.0-58.3
SMM, kg (SD)	28.7 (7.7)	33.0 (8.1)	37.0 (8.1)
Range	16.0-47.1	19.0-50.5	22.1-57.4
LBM, kg (SD)	52.6 (12.8)	59.7 (13.8)	67.2 (13.8)
Range	31.2-86.2	36.7-88.7	41.9-100.9
ASMI, kg/m^2 (SD)	7.4 (1.4)	8.6 (1.3)	9.9 (1.4)
Range	4.5-11.1	5.9-11.1	6.9-12.3
Phase angle, (SD)	4.6 (0.9)	5.0 (0.9)	4.7 (0.8)
Range	2.7-7.2	3.1-7.6	3.2-6.9

using the Tukey method given multiple comparisons. Analyses were performed using Microsoft Excel (Microsoft Corporation, Redmond, Washington) and SAS statistical software version 9.4 (SAS Institute, Inc., Cary, NC).

Results

A total of 219 patients underwent body composition assessment. The mean age was 62.1 (SD: ±11.0) years, mean BMI was 34.3 (±8.7) kg/m^2, and 53.8% of patients were female. A total of 134 (65.8%) patients met criteria for obesity. Females had greater PBF and lower SMM, ASMI, and LBM than males. Table 1 contains demographic and body composition parameters for all patients.

The sarcopenia and obesity phenotype classifications were as follows: not sarcopenic or obese, 26.0%; obese not sarcopenic, 59.4%; sarcopenic nonobese, 8.2%; and sarcopenic obese, 6.4%. Relative risk for sarcopenia in nonobese patients compared to obese patients was 2.47 (95% confidence interval: 1.30-4.68; $P = .0045$). Classification by sex is reported in Table 2. Body composition parameters for each group are reported in Table 3. Obese not sarcopenic patients had the highest BMI (39.4 kg/m^2), BFM (52.9 kg), PBF (45.7%), and ASMI (9.0 kg/m^2). Age was higher in sarcopenic obese (69.6 years) and sarcopenic nonobese (67.3 years) patients than in patients with obesity not sarcopenia (62.0 years) or neither sarcopenia nor obesity (58.9 years). Patients with sarcopenia, irrespective of obesity status, had lower ASMI, BMI, and SMM than patients without sarcopenia (Table 3). Increasing age was associated with higher odds of sarcopenia alone (OR: 1.08 [1.03-1.12], $P = .0007$); however, there was no difference based on male sex (OR: 1.39 [0.66-2.95], $P = .3909$). In sarcopenic obesity, increasing age was associated with higher odds (OR: 1.08 [1.02-1.15], $P = .0087$) and there was no difference based on sex (male OR: 3.13 [0.95-10.31], $P = .0605$). Body composition parameters for nonobese (BMI <30 kg/m^2), obese (BMI 30-<40 kg/m^2), and morbidly obese (≥40 kg/m^2) patients are provided in Table 4. All body composition parameters increased with higher BMI grouping, including the ASMI of 7.4, 8.6, and 9.9 kg/m^2 for nonobese, obese, and morbidly obese patients, respectively.

Discussion

In this study, we found nearly 15% of patients were classified as sarcopenic nonobese or sarcopenic obese and approximately two-thirds of patients were classified as obese using quantitative body composition parameters. Sarcopenic patients were older and had lower BMI than those without sarcopenia. When assessing patients based on BMI-based obesity grouping, all quantitative measures of muscle and fat were found to increase. Notably this included the ASMI, a parameter commonly used to classify patients as having sarcopenia.

Given limitations of BMI to describe body type and emerging evidence that reductions in BMI may not correlate with improvements in clinical outcomes, interest in alternative measures of body composition has recently increased. PBF has been demonstrated as having stronger associations with postoperative functional outcomes, hospital length of stay, and discharge to a care facility after TJA [48,49]. However, PBF or other measures of local adiposity have not been definitively linked with increased risk for PJI [50]. In contrast, evidence for the association of sarcopenia with an increased risk for postoperative complications within orthopaedics is increasing. Hendrickson et al. found sarcopenia to be associated with an increased risk for mortality in patients undergoing reconstructive surgery for sarcoma [25]. Hirase et al. found sarcopenia was associated with a significantly higher risk for reoperation, discharge to a care facility, and longer length of stay after spine surgery [23]. Data specific to TJA are limited, though Babu et al. identified central sarcopenia with risk for PJI [27]. Ardeljan et al. found sarcopenia was associated with increased length of stay, 90-day complications, and reoperation following total knee arthroplasty; however, this study was performed using claims data and without individual assessments of muscle mass or performance [28]. It has yet to be determined whether classifying patients based on phenotype, such as sarcopenic or sarcopenic obese or quantitative assessment of individual measurements, such as PBF, is superior.

This study utilized BIA to assess body composition due to its potential to be integrated into routine clinical visits because it can be performed quickly, there is no ionizing radiation, test results are obtained immediately, and it can be carried out by clinic staff. While there is a capital cost associated with the device, there are limited additional material costs and it does not require a specialized technician or radiologist to perform manual segmentation of imaging. These factors make it an ideal modality for longitudinal assessments to track presurgical optimization for a high-risk patient. Anthropometrics, dual-energy x-ray absorptiometry, BIA, computed tomography, and magnetic resonance imaging have all been used to assess body composition, though they are challenging in the clinical setting due to cost, radiation, and availability [51].

While BIA may systematically underestimate fat in more obese patients, it has been validated as a useful and accurate clinical tool for body composition measurements, including in the obese population [40,52].

Ji et al. reported sarcopenia prevalence ranging from 25.7% to 44.1% and sarcopenic obesity prevalence between 1.8% and 21.2% within a Korean aorthopaedic practice setting [53]. Nishigori et al. evaluated patients undergoing laparoscopic gastrectomy and found 24% to be sarcopenic obese and 33% with sarcopenia not obesity [30]. While a variety of methods to categorize sarcopenia exist, there is not a universal standard and prevalence has been found to vary based upon the diagnostic criteria applied [54]. Quantitative assessments of muscle used to define the presence of sarcopenia are often determined using epidemiologic studies within a country and selecting lower percentiles as a cutoff. However, the wide range of body composition among individuals or national populations, use of different methods to assess muscle and fat parameters, and difficulty in interpreting these measurements, in contrast to a routine blood chemistry test, contribute to the challenge of establishing prevailing diagnostic criteria. This study found a wide range of body composition parameters, based on sarcopenia-obesity phenotype.

Some have advocated for a definition using multiple parameters, such as low muscle strength, low muscle quantity or quality, and low physical performance [21]. Muscle performance assessment has emerged in recent years as a surrogate measure correlating with postoperative function, though there is not yet consensus regarding the optimal method [55–58]. Tests of gait speed or lower extremity mechanics may be indicative of poor global muscle function; however, these can be confounded by arthritis-associated pain and dysfunction of the lower extremities or mobility. Some have used standardized and validated measures of upper body functional strength, such as maximal handgrip strength, to assess sarcopenia. The time course and relationship of adverse changes in muscle quantity, composition, and performance is not well understood, particularly in the setting of age-related changes in body composition and transition to a more sedentary state due to lower extremity arthritic changes. It is not clear whether quantitative measurements of muscle precede changes in performance, or vice versa, and whether upper and lower extremities are impacted similarly. Longitudinal assessments of body composition during progression of would be valuable in better quantifying the natural history of this process.

This study identified patients with a higher BMI also had a higher ASMI. While it is intuitive to conclude patients with a higher BMI would often have greater amounts of skeletal muscle as additional force is required for mobility and muscle experiences greater loads due to higher body weight, it does create a diagnostic problem with sarcopenic obesity. Increased ASMI in this unique group may lead to underdiagnosis of this problem, as their ASMI exceeds typical population definitions used for sarcopenia from younger, healthier patients [54]. In this study, the mean BMI for sarcopenic nonobese and sarcopenic obese were 26.2 kg/m^2 and 33.1 kg/m^2, respectively. While there is a large amount of muscle in association with a higher BMI, there is also a large amount of adipose tissue in the sarcopenic obese. It is possible considering weight or BMI-specific cutoffs or use of alternative parameters, such as ratios of fat to muscle, may be of value in categorizing patients who are obese or morbidly obese with sarcopenia. Further studies to determine the range of muscle or fat quantity and develop specialized diagnostic criteria for sarcopenia in the morbidly obese are needed.

This study is not without limitations. The prevalence of sarcopenia and sarcopenic obesity reported in this study is dependent on the selected diagnostic criteria, and alternative definitions may result in different prevalence, as previously demonstrated [54]. We selected a modern definition derived from a North American cohort using the ASMI to potentially limit the impact of added truncal mass seen in the obese and morbidly obese [41]. We believe this is more generalizable to the study population than criteria derived from regions of the world where obesity is less common. Additionally, the study was performed using a single surgeon's practice at an academic medical center, and prevalence could vary based on a different practice setting or geographic region. There are not universally agreed upon normal ranges for body composition parameters or diagnostic criteria for sarcopenia applicable to all patients. Aggregation of large amounts of data with routine testing, using a single diagnostic modality, and across multiple practice settings could contribute to improved standardization of assessment and diagnostic criteria for sarcopenia and sarcopenic obesity. It could be particularly valuable to obtain an improved understanding of population values for body composition parameters such as the ASMI and PBF in a country increasingly impacted by an obesity epidemic [47].

Conclusion

This study found sarcopenia to be present in nearly 15% of patients presenting to an adult reconstruction clinic using quantitative muscle assessment with BIA. Body composition was found to vary considerably based on both classifications of sarcopenia-obesity using BIA or traditional BMI-based definitions of obesity. Given difficulty with prescribed weight loss and limitations inherent to use of BMI as a method of risk assessment, orthopaedic surgeons should consider adoption of more routine screening for sarcopenia. While evidence is emerging that sarcopenia is associated with postoperative complications following orthopaedic procedures, further research is necessary to develop improved diagnostic criteria and determine whether phenotypic categorization of sarcopenia is superior to BMI for perioperative risk stratification.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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