

Quantitative 3D-CT imaging of sarcopenia mitigation in the elderly: evidence from a case report

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Abstract

This case study examines the effectiveness of using combined CT imaging and 3D imaging in monitoring the prevention of sarcopenia through continuous daily exercises in an elderly patient. Using a 256-slice CT scanner with dose reduction technology and advanced muscle segmentation with the open-source software DAFNE, we compared changes in muscle mass and density in a 70-year-old patient in 2014 and in 2023. The obtained images allowed the creation of detailed 3D models for a more accurate and intuitive assessment of the leg musculature. Despite aging, the results of the scans performed at the beginning and end of the study period did not show significant changes in the patient's musculature, suggesting that a persistent Full-Body in-Bed Gym protocol ("Gym Bed" exercise routine) can effectively contribute to maintaining muscle mass and density in the elderly. These preliminary results highlight the potential of advanced imaging techniques not only to diagnose but also to quantify the effectiveness of non-pharmacological interventions against sarcopenia

Key Words: Quantitative 3D-CT Imaging; sarcopenia mitigation in elderly; full-body in-bed gym.

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Sarcopenia, an age-related degenerative condition, is characterized by the progressive loss of muscle mass and strength, becoming particularly evident after the age of 60. This muscle deterioration not only reduces mobility and compromises the independence of the elderly but also increases the risk of falls and injuries, exacerbating pre-existing health conditions such as osteoarthritis and diabetes. The consequent decline in quality of life negatively impacts physical, psychological, and social aspects.¹ Therefore, it is essential to intervene with physical exercise, a proper diet, and a healthy lifestyle to prevent or slow the progression of sarcopenia and improve the well-being of the elderly.²⁻⁸ In this context, Computed Tomography (CT) emerges as an essential diagnostic tool, offering a high-precision imaging methodology for quantifying muscle mass.⁹ Through high-resolution image acquisition, CT allows for clear differentiation of soft tissues and accurate measurement of muscle tissue quantity and quality. The capabilities of this tool include detecting muscle density and measuring variations in muscle volume, both key indicators in the diagnosis and management of sarcopenia.¹⁰⁻¹³ The ability of CT to provide precise and reliable measurements of body composition is crucial not

only for diagnosis but also for monitoring the effectiveness of therapeutic interventions. Additionally, this technology allows for the examination of the distribution of fat and muscle in the body, providing valuable details that can influence sarcopenia management and treatment strategies. This case study illustrates the use of CT in a longitudinal experimental case report aimed at evaluating the effectiveness of a daily exercise routine, called persistent Full-Body in-Bed Gym protocol ("Gym Bed" exercise routine), in preventing sarcopenia in an elderly patient. Starting in 2014 at the age of 70, the patient followed this home routine for ten years, during which he maintained a consistent physical activity regimen and underwent CT scans to monitor his muscle mass and density.

At the beginning of the study (2014) and ten-years after in 2023, CT scans were performed to visually quantify and measure changes in muscle composition and density. These data provided a detailed view of the effect of "Gym Bed" exercises on preventing muscle loss, highlighting how non-pharmacological interventions can substantially mitigate the risks associated with sarcopenia and maintain muscle functionality in the elderly. This case thus offers valuable insights into the effectiveness of light but regular exercises

and the role of CT as an objective and detailed evaluation tool in geriatric research.

Materials and Methods

The subject of this study is a 70-year-old man at the start of the study in 2014. This patient was selected for his predisposition to follow a home exercise regimen and his willingness to undergo medical evaluations and CT scans in 2014 and in 2023. He did not present any conditions that could influence sarcopenia aside from normal aging.

The patient adopted a daily "Gym Bed" routine, a low-intensity exercise program designed to be performed in bed, aimed at maintaining muscle strength and mitigating sarcopenia. This routine was performed every morning for about 30 minutes and included stretching, isometric muscle contractions, and light joint movements.¹⁴⁻¹⁶ For a dynamic presentation of the Full-Body in-Bed Gym sessions refer to the video accessible through this link: <https://youtu.be/pCHKmxCLYFs>.¹⁷

Advanced computed tomography (CT) techniques were used to monitor the patient's muscle mass and density. The initial CT scan was performed in 2014, using a 256-slice CT scanner capable of high-resolution scans with contiguous 0.5 mm slices, offering detailed visualization of muscle composition. Dose reduction technology was employed to minimize the patient's radiation exposure. In 2023, at the end of the study, another scan was performed with the same device and technical specifications to ensure data comparability. The acquired images were processed using the open-source software DAFNE for muscle segmentation, allowing detailed measurement of muscle density in Hounsfield Units (HU) and the creation of 3D models of the musculature. Muscle density measurements and volumetric analyses of the lower leg muscles were compared between the initial and final scans to identify any changes over time. Quantitative analysis was supported by the DAFNE software,¹⁸ which enabled accurate and reproducible assessment of muscle composition changes.

Ethical Considerations. The study was conducted in full compliance with ethical standards. The patient provided written informed consent, understanding the nature and purpose of the study, as well as the imaging procedures to which he would be subjected.

Results

During the decade-long longitudinal study, data obtained from CT scans performed at the beginning (2014) and at the end (2023) of the study period were meticulously analyzed to identify changes in the patient's lower leg muscle composition (Figure 1).

CT scans revealed that the patient's lower leg muscle mass remained remarkably stable over the decade. Volumetric measurements of major lower leg muscle groups (such as the gastrocnemius, soleus, and tibialis anterior) showed no significant changes, with a deviation of less than 1% between the two scans. This result is particularly noteworthy considering the patient's advanced age and the muscle de-

cline generally associated with aging. Muscle density measurements, performed in Hounsfield Units (HU), confirmed minimal variation in lower leg muscle tissue density. Despite slight fluctuations, density remained well within the range considered normal for maintaining muscle function, with variations between -2% and +1% compared to the initial measurement.

A detailed comparison between initial and final scans highlighted the stability in the size and shape of the analyzed lower leg muscles. These results were visualized through 3D reconstructions, providing a clear visual representation of the lack of muscle deterioration (Figure 1).

Detailed analysis of the lower leg muscle tissue demonstrated the absence of significant fatty atrophy, a common indicator of advanced sarcopenia. This was considered a positive indicator of the effectiveness of "Gym Bed" exercises in maintaining not only muscle mass but also the quality of muscle tissue (Figure 2).

No new irregularities or abnormalities in muscle tissue and surrounding areas were detected during the study period. This indicates a general maintenance of muscle and structural health, beyond mere measurements of mass and density (Table 1).

Discussion

The results obtained in this case report highlight the effectiveness of "Gym Bed" exercises in preventing sarcopenia in elderly. Despite the natural physical decline associated with aging, the patient's muscle mass and density remained stable over ten years. This result is consistent with existing literature supporting the use of regular physical exercise

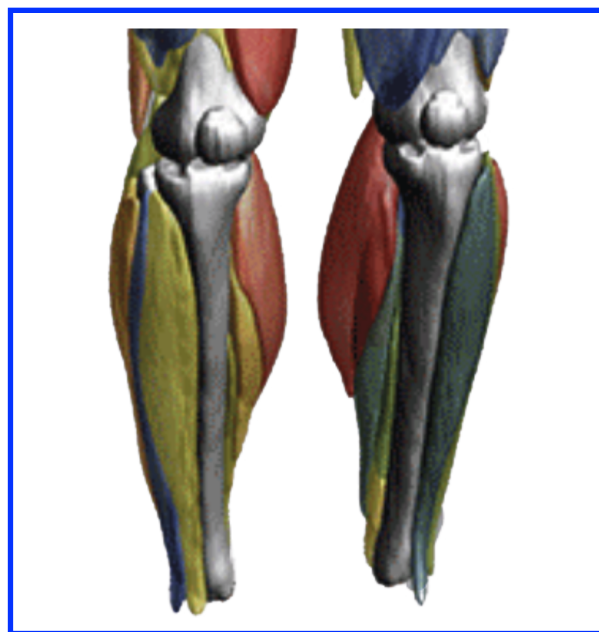


Figure 1. 3D reconstruction of lower left and right leg musculature showing in 2023 stable muscle mass and density.

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routines as a preventive strategy against age-related muscle loss. Indeed, previous studies have shown that physical activity can improve muscle function and increase the longevity of muscle tissues, even in old age.¹⁻⁸

This is essentially based on the fact that the vast majority of elderly people are poorly trained if not highly sedentary. Therefore, any increase in daily physical activity, if maintained consistently, can rejuvenate the muscles, *i.e.*, compensate for the inevitable loss of muscle structure and function that occurs linearly throughout life, starting from the age of 30 and increasing after the age of 70.¹⁹⁻²²

The use of computed tomography in our study allowed for a detailed and quantitative assessment of muscle composition. This approach provided an objective measurement of

physical changes, demonstrating that advanced imaging technologies are valuable tools not only for diagnosis but also for monitoring chronic conditions.^{9-13,18} In particular, the ability to visualize subtle changes in muscle tissue with high precision significantly contributed to validating "Gym Bed" exercises as an effective method for maintaining muscle health. The dose reduction technology used also ensured that the benefits of CT use were not overshadowed by the harmful effects of excessive radiation exposure, emphasizing the importance of balancing patient safety with high-quality data acquisition.

Comparing our results with those of other similar studies, it emerges that regular, even low-intensity exercise can be sufficient to combat sarcopenia, provided it is consistent

Table 1. Comparison of lower leg muscle parameters between 2014 and 2023.

Parameter	2014	2023	Change (%)
Lower leg muscle mass (cm ³)	1100	1095	-0.45
Muscle density (HU)	35	34.3	-2.00
Gastrocnemius (cm ³)	400	398	-0.50
Soleus (cm ³)	300	299	-0.33
Tibialis anterior (cm ³)	250	249	-0.40
Adipose tissue (cm ³)	150	153	+2.00

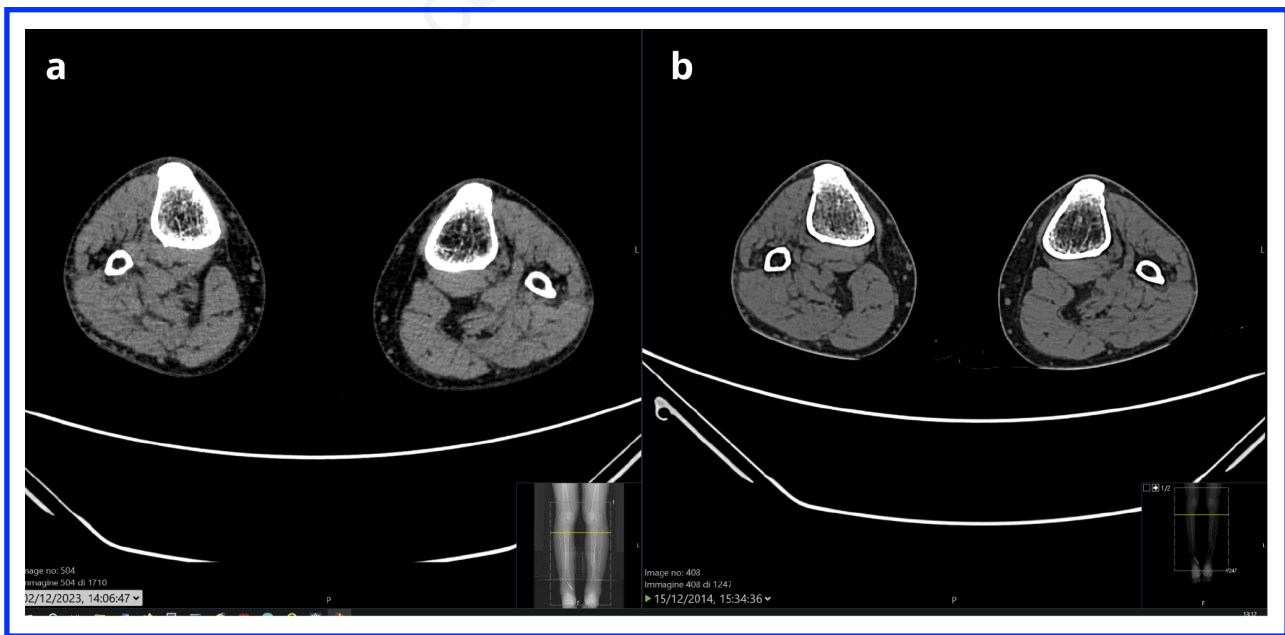


Figure 2. Comparison of axial CT images of the lower legs. Image A (left): CT scan from 2023. Image B (right): CT scan from 2014. No significant changes are observed between the two scans, indicating an unchanged clinical situation over the observation period.

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and tailored to individual needs. This aligns our findings with current research proposing exercise as an essential component in maintaining physical health in the elderly.

A limitation of this study is its nature as a single case study, which, while offering in-depth details on an individual, does not allow generalization of the results to a broader population without further research. On the other hand, a recent study aimed to assess the impact of a home Full-Body in-Bed Gym protocol on quality of life, pain and risk of sarcopenia in elderly subjects, demonstrated a significant enhancement in their quality of life, as indicated by the 12-Item Short Form Health Survey (SF-12) Mental Component Summary ($p=0.04$), and an improvement in pain levels ($p=0.03$). Although not statistically significant, there was also an improvement in sarcopenia risk. Patients were given the freedom to decide whether to continue treatment after the evaluation of outcomes. Patient compliance with the exercise protocol over six months indicated its feasibility and sustainability, even in the long term. These findings suggest that the Full-Body in-Bed Gym protocol may play a valuable role in mitigating age-related muscle loss, emphasizing the importance of further investigation into such rehabilitation and prevention strategies. Future studies could expand the sample of participants and include groups with different physical and medical backgrounds to further explore the effectiveness of "Gym Bed" exercises in varied contexts.¹⁶

In conclusion, the results of this study support the idea that non-pharmacological interventions, such as daily "Gym Bed" exercises, are effective in maintaining muscle mass and density in the elderly, significantly contributing to sarcopenia prevention and improving quality of life.¹⁶ This study adds to the growing evidence that physical exercise should be a standard component in elderly health management strategies, particularly for those at risk of cachexia. Further research is needed to determine the specifics of the type, duration, and frequency of the most effective exercises to combat sarcopenia in different populations and physical conditions.

List of abbreviations

3-D: Tridimensional

CT: Computed Tomography

DAFNE: Deep Anatomical Federated Network

IRCCS: Istituto di Ricovero e Cura a Carattere Scientifico

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tools necessary for advanced muscle segmentation and analysis.

Conflict of interest

The authors declare no potential conflict of interest, and all authors confirm accuracy.

Ethics statement

No ethical committee approval was required for this case report by the Department, because this article does not contain any studies with human participants or animals. Informed consent was obtained from the patient included in this study.

Patient consent for publication

Written informed consent was obtained from the patient for anonymized patient information to be published in this article.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

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