Radiologic Biomarkers in Lifestyle Medicine: Imaging as an Objective Endpoint of Behavioral Interventions.

Abstract

Background: Lifestyle medicine relies on behavioral interventions to prevent and reverse chronic disease, yet outcome measurement often depends on self-reported data, serum biomarkers, or long-term clinical endpoints requiring years of follow-up. Advanced imaging modalities offer objective, organ-specific, and quantifiable surrogate endpoints that can detect structural changes over clinically relevant timeframes of 6–24 months.

Objective: To synthesize current evidence on radiologic biomarkers across four disease domains—metabolic dysfunction-associated steatotic liver disease (MASLD), atherosclerosis, osteoporosis, and sarcopenia—that demonstrate responsiveness to lifestyle interventions, and to propose a practical Imaging-Guided Lifestyle Medicine (IGLM) framework for clinical and research application.

Methods: A narrative review was conducted through systematic searching of PubMed, Scopus, and Embase (2010–2025) for clinical trials, prospective cohort studies, and systematic reviews using imaging as an outcome of behavioral interventions. Evidence was synthesized by organ system.

Results: MRI-PDFF accurately quantifies hepatic steatosis with high sensitivity to lifestyle-induced changes; a 30% or greater relative reduction correlates with histologic improvement. Carotid intima-media thickness measured by ultrasound responds to combined dietary and exercise interventions within 6–24 months. DXA-measured bone mineral density shows statistically significant improvements with resistance and weight-bearing exercise in postmenopausal women. CT-based skeletal muscle index at the L3 vertebral level provides precise body composition data, with resistance training demonstrating measurable increases in lean mass and reductions in myosteatosis.

Conclusion: Radiologic biomarkers provide reproducible, organ-specific evidence of disease reversibility through lifestyle interventions. The proposed IGLM framework offers a tiered approach integrating cost-effective imaging into clinical practice and research trial design. Standardized imaging protocols for behavioral intervention trials are needed to advance the field.

Keywords: imaging biomarkers, lifestyle medicine, MASLD, atherosclerosis, osteoporosis, sarcopenia, MRI-PDFF, DXA, carotid intima-media thickness, body composition

34

1. Introduction

Lifestyle medicine has emerged as a recognized medical specialty focusing on the use of evidence-based behavioral interventions—including dietary modification, physical activity, sleep optimization, stress management, and substance avoidance—for the prevention, treatment, and reversal of chronic disease [1]. The global burden of non-communicable diseases (NCDs), which account for approximately 74% of all deaths worldwide according to the World Health Organization, underscores the urgent need for scalable and effective lifestyle-based interventions [2].

Despite growing evidence supporting the efficacy of behavioral interventions, a persistent challenge in lifestyle medicine has been the reliable measurement of treatment response. Current outcome assessment approaches often rely on self-reported adherence data, which are subject to recall and social desirability biases; laboratory biomarkers such as serum lipids or liver enzymes, which reflect systemic processes but lack organ-specific resolution; or long-term hard clinical endpoints such as mortality, major adverse cardiovascular events (MACE), or fracture incidence, which require years of follow-up and large sample sizes to demonstrate statistical significance.

This limitation has practical consequences. In clinical settings, patients and clinicians lack objective feedback on the structural impact of behavioral changes at the organ level. In research, the absence of sensitive intermediate endpoints contributes to the high cost and duration of lifestyle intervention trials, limiting the pace of evidence generation.

Advanced medical imaging has the potential to address this gap. Contemporary imaging modalities can non-invasively quantify organ-specific pathology—hepatic fat content, arterial wall thickness, bone mineral density, and skeletal muscle mass—with high accuracy and reproducibility. Importantly, several of these imaging biomarkers have been shown to be responsive to lifestyle interventions over clinically manageable timeframes of 3–24 months, positioning them as practical surrogate endpoints.

This narrative review examines the current evidence on radiologic biomarkers across four disease domains that are central to lifestyle medicine practice: metabolic dysfunction-associated steatotic liver disease (MASLD, formerly NAFLD), atherosclerosis, osteoporosis, and sarcopenia. For each domain, we evaluate the available imaging modalities, the evidence for disease reversibility through behavioral interventions, and the clinical utility and limitations of each approach. We then propose an integrative Imaging-Guided Lifestyle Medicine (IGLM) framework to guide the practical application of imaging in both clinical care and research trial design.

2. Methods

This narrative review was conducted through a structured search of the PubMed, Scopus, and Embase databases for articles published between January 2010 and December 2025. Search terms included combinations of: “imaging biomarker,” “lifestyle intervention,” “diet,” “exercise,” “physical activity,” and “behavioral intervention,” combined with disease-specific terms (“NAFLD,” “MASLD,” “hepatic steatosis,” “atherosclerosis,” “carotid intima-media thickness,” “coronary artery calcium,” “osteoporosis,” “bone mineral density,” “sarcopenia,” “skeletal muscle index,” and “myosteatosis”).

Eligible studies included randomized controlled trials, prospective cohort studies, and systematic reviews or meta-analyses that used at least one imaging modality as a primary or secondary outcome measure for evaluating the response to a behavioral lifestyle intervention. We prioritized studies with sample sizes exceeding 20 participants and intervention durations of at least 8 weeks. Landmark studies published before 2010 that were foundational to the field were also included when relevant.

Given the heterogeneity of imaging modalities and intervention types across the four disease domains, a formal systematic review methodology was not applied. Instead, evidence was synthesized narratively, organized by organ system and disease domain, with emphasis on the magnitude of imaging-measured changes, the timeframes required for detectable change, and the practical feasibility of each modality.

3. MASLD / NAFLD: Hepatic Fat Quantification

3.1 Imaging Modalities

Magnetic resonance imaging–derived proton density fat fraction (MRI-PDFF) has emerged as the most accurate non-invasive tool for quantifying hepatic steatosis. MRI-PDFF demonstrates strong correlation with histologic fat grading (r = 0.82–0.85) and high diagnostic accuracy (AUC 0.989) for detecting the presence of steatosis [3,4]. The technique is reproducible across different MRI scanner platforms and field strengths, making it suitable as a primary endpoint in clinical trials [5]. A key meta-analytic finding has established that a 30% or greater relative decline in MRI-PDFF is associated with higher odds of histologic response and resolution of non-alcoholic steatohepatitis (NASH), providing a clinically validated imaging threshold [6].

Transient elastography (FibroScan) combines two complementary measurements: the controlled attenuation parameter (CAP) for steatosis quantification and liver stiffness measurement (LSM) for fibrosis staging. While CAP is less accurate than MRI-PDFF for precise fat quantification—a comparative analysis showed an AUC of 0.73 for CAP versus 0.99 for MRI-PDFF in differentiating steatosis grades [5]—it offers significant practical advantages in terms of portability, cost, and ease of use in primary care and community clinic settings.

MR elastography (MRE) enables non-invasive fibrosis staging with high diagnostic accuracy and is particularly valuable for monitoring the fibrosis component of MASLD, which carries the greatest prognostic significance. Ultrasound-based methods, including hepatorenal index and attenuation imaging, remain the most accessible but provide semi-quantitative assessments that are less sensitive to small changes over time.

3.2 Evidence of Reversibility with Lifestyle Interventions

The evidence supporting imaging-detected reversal of hepatic steatosis through lifestyle modification is robust. A pivotal randomized controlled trial by Vilar-Gomez and colleagues demonstrated a dose-response relationship between weight loss and histologic improvement in NASH: body weight reduction of 5% or more was required to reduce hepatic steatosis, 7–10% to improve liver inflammation, and 10% or greater to achieve fibrosis regression [7,8].

Exercise training, independent of significant weight loss, has also demonstrated meaningful reductions in liver fat. A systematic review and meta-analysis by Stine et al. (2023), including 14 randomized controlled trials with 551 participants, found that exercise training participants were 3.5 times more likely to achieve a 30% or greater relative reduction in MRI-measured liver fat compared with controls (OR 3.51, 95% CI 1.49–8.23, P = 0.004). This treatment

response was independent of clinically significant weight loss of 5% or more. An exercise dose of at least 750 MET-minutes per week—equivalent to approximately 150 minutes per week of brisk walking—was required to achieve this threshold (OR 3.73, 95% CI 1.34–10.41) [9].

The American College of Sports Medicine roundtable statement on NAFLD recommends at least 150 minutes of moderate or 75 minutes of vigorous-intensity physical activity per week for all patients with NAFLD, including those with compensated cirrhosis, with aerobic exercise combined with resistance training as the preferred modality [10].

The Mediterranean dietary pattern has shown particular promise in reducing liver fat even without significant caloric restriction or weight loss, attributed to anti-inflammatory and insulin-sensitizing effects. This is the dietary pattern currently recommended by the EASL–EASD–EASO Clinical Practice Guidelines for NAFLD management [11].

Regarding the timeline of detectable imaging changes, steatosis reduction on MRI-PDFF can be observed within 8–12 weeks of intervention initiation, while fibrosis regression on MRE typically requires 6–12 months or longer [5].

3.3 Clinical Utility and Limitations

MRI-PDFF is the preferred endpoint in clinical trials due to its accuracy, reproducibility, and validated thresholds for treatment response. However, its cost and limited availability restrict routine clinical use, particularly in low-resource settings. FibroScan provides a practical alternative for longitudinal monitoring in community clinics, although its higher failure rate in obese patients and lower precision for quantifying steatosis severity limit its utility as a research endpoint [5]. A tiered approach—using FibroScan for initial screening and longitudinal monitoring, with MRI-PDFF reserved for trial settings or clinical decision-making at key thresholds—represents a pragmatic strategy.

4. Atherosclerosis: Vascular Imaging

4.1 Imaging Modalities

Carotid intima-media thickness (cIMT) measured by high-resolution B-mode ultrasound is one of the most extensively studied surrogate markers of subclinical atherosclerosis. A cIMT of 0.7 mm or greater is associated with increased cardiovascular disease risk, and the measurement has been validated as a predictor of future cardiovascular events in large prospective studies [12,13]. A major systematic review and meta-regression by the PROG-IMT consortium, analyzing data from 119 randomized controlled trials involving 100,667 patients, confirmed the association between intervention effects on cIMT progression and cardiovascular disease risk [14].

Coronary artery calcium scoring (CACS) using non-contrast cardiac CT provides direct visualization and quantification of calcified coronary plaque burden using the Agatston scoring system. CAC scoring has been incorporated into ACC/AHA guidelines for cardiovascular risk assessment, with a score of zero indicating very low short-term risk and scores of 100 or above supporting statin initiation [15]. The 2024 ESC guidelines further emphasize CAC scoring in reclassifying risk for individuals with low pre-test probability of coronary artery disease [16].

CT coronary angiography (CCTA) provides additional information on plaque volume and composition, enabling the distinction between calcified (stable) and non-calcified (potentially vulnerable) plaques. Arterial inflammation can be quantified using 18F-FDG PET/CT, though this modality is primarily limited to research settings due to cost and radiation exposure.

4.2 Evidence of Reversibility with Lifestyle Interventions

The Lifestyle Heart Trial, a landmark randomized controlled trial by Ornish and colleagues, demonstrated that intensive lifestyle changes—comprising a low-fat vegetarian diet, moderate exercise, stress management training, and smoking cessation—led to regression of coronary atherosclerosis as measured by quantitative coronary angiography. After one year, the average percentage diameter stenosis decreased from 40.0% to 37.8% in the experimental group while progressing from 42.7% to 46.1% in the control group. Notably, 82% of experimental group patients showed a trend toward regression. At five-year follow-up, even greater regression was observed in the experimental group (3.1 absolute percentage point decrease), while the control group showed continued worsening (11.8 percentage point increase, P = 0.001) [17,18].

Regarding cIMT specifically, several interventional studies have demonstrated that combined dietary and exercise interventions can blunt or reverse age-associated carotid

thickening. A systematic review of cross-sectional and interventional studies found that lifestyle modifications involving dietary recommendations, smoking cessation, weight control, and exercise could significantly regress cIMT. One controlled prospective study of 1,390 individuals showed a 6.8% regression in carotid IMT over two years in hypercholesterolemic men receiving lifestyle counseling [19]. A preliminary study of six months of supervised aerobic exercise with dietary modification in sedentary African American adults showed a 7.3% reduction in carotid IMT (0.617 ± 0.092 mm to 0.572 ± 0.068 mm, P = 0.013) [20].

The relationship between physical activity and coronary artery calcium is more complex. A large cohort study published in JAMA Cardiology (2024) found that physical activity volume was not associated with progression of CAC in men and women initially free of overt cardiovascular disease, challenging earlier cross-sectional observations linking high-volume exercise with higher CAC scores [21]. Importantly, CAC progression in physically active individuals may reflect plaque stabilization (shift from non-calcified to calcified composition) rather than disease worsening, a phenomenon analogous to that observed with statin therapy [22].

4.3 Clinical Utility and Limitations

cIMT measurement offers the most practical option for monitoring lifestyle intervention effects: it is non-invasive, inexpensive, radiation-free, and can be performed at the point of care. However, measurement variability between operators and sites remains a limitation, and standardized protocols are essential for serial assessments. CAC scoring provides strong prognostic value but is less suitable for monitoring short-term lifestyle changes due to the paradox of calcification reflecting stabilization rather than regression. Serial CAC scoring specifically for lifestyle intervention monitoring is not currently recommended in clinical guidelines [15]. A major challenge across all vascular imaging studies is separating the independent effects of lifestyle modification from concurrent pharmacotherapy (particularly statins), as many patients in these populations receive both interventions simultaneously.

5. Osteoporosis: Bone Density and Microarchitecture

5.1 Imaging Modalities

Dual-energy X-ray absorptiometry (DXA) remains the clinical standard for bone mineral density (BMD) assessment, providing areal BMD measurements at the lumbar spine and proximal femur with T-score classification for osteoporosis diagnosis (T-score ≤ −2.5) and osteopenia (−2.5 < T-score < −1.0). DXA is widely available, delivers minimal radiation exposure, and is reimbursable in most healthcare systems [23].

Quantitative CT (QCT) provides volumetric BMD measurements with the ability to differentiate cortical from trabecular bone compartments, offering greater anatomic resolution than DXA. High-resolution peripheral QCT (HR-pQCT) enables assessment of bone microarchitecture at the distal radius and tibia, providing detailed information about trabecular and cortical structural parameters. Trabecular bone score (TBS) is a DXA-derived textural analysis that provides supplementary information about bone microstructure without requiring additional imaging [23].

5.2 Evidence of Reversibility with Lifestyle Interventions

A large body of meta-analytic evidence supports the positive effect of exercise on BMD in postmenopausal women. Kemmler et al. (2023), in an updated systematic review and meta-analysis of 80 studies involving 5,581 participants, found statistically significant exercise effects on BMD at the lumbar spine (SMD = 0.29, 95% CI 0.16–0.42), femoral neck (SMD = 0.27, 95% CI 0.16–0.39), and total hip (SMD = 0.41, 95% CI 0.30–0.52). These positive effects were consistent across early and late postmenopausal women and were observed in both supervised and non-supervised programs [24].

A 2025 meta-analysis specifically evaluating resistance training parameters in 17 randomized controlled trials (690 subjects) found that resistance training significantly improved BMD at the lumbar spine (SMD = 0.88, 95% CI 0.21–1.56, P = 0.01) and femoral neck (SMD = 0.89, 95% CI 0.40–1.39, P = 0.0004). Moderate-intensity training performed three times per week appeared to be the most effective protocol [25]. Combined weight-bearing and resistance training programs showed similarly positive effects (SMD 0.42, 95% CI 0.23–0.61 at the lumbar spine) [26].

Nutritional factors, particularly adequate calcium, vitamin D, and protein intake, demonstrate additive effects when combined with exercise interventions. However, bone remodeling cycles typically require 3–4 months, and achieving a new stable level of bone mass change generally requires 7–9 months of sustained intervention [25].

An important clinical consideration is the potential for conflict between interventions targeting MASLD (caloric restriction for weight loss) and bone health preservation, as weight loss—particularly rapid weight loss—can reduce BMD. Integrated intervention strategies that combine moderate caloric deficit with adequate protein intake and targeted resistance exercise are essential to manage these competing demands.

5.3 Clinical Utility and Limitations

DXA is the most practical imaging modality for monitoring exercise-related bone changes, but its least significant change (LSC) of approximately 3–5% limits sensitivity to short-term interventions. Meaningful BMD changes are most reliably detected over periods of 12 months or longer. HR-pQCT offers greater sensitivity to microarchitectural changes but remains restricted to research settings. The minimum intervention duration of 6 months in most exercise-BMD trials reflects the biological requirement for sufficient mechanical stimulation to trigger adaptive skeletal remodeling [24].

6. Sarcopenia: Body Composition Imaging

6.1 Imaging Modalities

The assessment of skeletal muscle mass and quality has been transformed by cross-sectional imaging techniques. CT imaging at the third lumbar vertebra (L3) level has become the most widely used method for quantifying skeletal muscle in clinical research. A systematic review by Defined et al. confirmed that L3 is the most commonly used abdominal landmark, employed in 123 of 142 studies assessing muscle mass and 45 of 49 studies evaluating myosteatosis. The skeletal muscle index (SMI), calculated as total cross-sectional muscle area at L3 normalized to height squared, is the most commonly used derived measure [27].

Muscle quality (myosteatosis) can be assessed through skeletal muscle radiodensity expressed in Hounsfield units (HU), where lower attenuation values indicate greater intramuscular fat infiltration. Established diagnostic cut-off points for myosteatosis are less than 33 HU for females and less than 41 HU for males [28]. Recently, the utility of opportunistic sarcopenia assessment from existing clinical CT scans has been demonstrated. Pickhardt et al. showed that automated deep learning-based muscle measurements at the L1 level compare favorably with L3 measurements for predicting adverse outcomes including hip fracture and death, greatly expanding the potential for opportunistic screening using routine chest and abdominal CT scans [29].

DXA provides appendicular lean mass index (ALMI) measurements used in the EWGSOP2 and AWGS2 diagnostic criteria for sarcopenia [30]. While practical and standardized, DXA cannot distinguish between lean tissue and intramuscular fat, limiting its ability to assess muscle quality. MRI offers the most detailed assessment of muscle volume and intermuscular adipose tissue without ionizing radiation, but cost and accessibility limit its use. Point-of-care ultrasound for muscle thickness and echogenicity assessment is an emerging modality with significant potential for community-level screening, though standardization protocols are still under development.

6.2 Evidence of Reversibility with Lifestyle Interventions

Progressive resistance training remains the most evidence-based intervention for reversing sarcopenia. Systematic reviews consistently demonstrate that resistance training promotes muscle hypertrophy through upregulation of protein synthesis and increases in type II muscle fiber size [31]. When combined with adequate protein supplementation (1.2 g/kg/day or more), synergistic effects on muscle mass and function have been observed.

Combined aerobic and resistance training is considered optimal for sarcopenic obesity, addressing both the muscle wasting and excess adiposity components simultaneously. Regarding imaging-detectable changes, exercise interventions of 12–24 weeks can produce measurable increases in skeletal muscle area and reductions in myosteatosis on CT, though the magnitude of change varies by intervention type, intensity, and participant characteristics.

An important clinical application is the use of CT-based body composition analysis for longitudinal monitoring in patients who undergo abdominal or thoracic imaging for other clinical indications. This “opportunistic” approach leverages existing imaging data to extract muscle and adipose tissue metrics without additional cost, radiation, or patient burden [29].

6.3 Clinical Utility and Limitations

CT L3 analysis provides the most precise quantification of muscle mass and quality but involves ionizing radiation and is not suitable for serial monitoring solely for sarcopenia assessment. DXA ALMI measurements offer a practical compromise for clinical settings, with standardized reference values and low radiation exposure, but lack sensitivity to muscle quality changes. The substantial variation in CT technical parameters (use of intravenous contrast, slice thickness, kilovoltage) across studies represents a significant barrier to establishing universal reference values and must be addressed through consensus guidelines [32].

7. Integrative Discussion

7.1 Cross-cutting Themes and Competing Interventions

A critical insight from synthesizing evidence across these four domains is the existence of competing demands between interventions targeting different organ systems. Caloric restriction and weight loss are strongly indicated for MASLD management (5–10% body weight reduction for histologic improvement) and cardiovascular risk reduction, but may simultaneously compromise bone mineral density and accelerate muscle wasting if not carefully managed.

This trade-off is not merely theoretical. Weight loss-associated bone loss is well documented, and the combination of caloric restriction with physical inactivity accelerates sarcopenia in older adults. Imaging provides a unique capability to monitor these competing effects simultaneously—tracking hepatic fat reduction alongside bone density and muscle mass changes—enabling clinicians to adjust intervention prescriptions based on objective, organ-specific feedback.

The underlying pathophysiologic connections between these conditions further support an integrated imaging approach. Chronic low-grade inflammation, insulin resistance, and physical inactivity represent shared risk factors for hepatic steatosis, atherosclerosis, osteoporosis, and sarcopenia. Sarcopenia itself has been identified as an independent risk factor for NAFLD and fibrosis progression [10]. These interconnections suggest that lifestyle interventions targeting common pathways may produce measurable imaging improvements across multiple organ systems simultaneously.

7.2 Proposed Framework: Imaging-Guided Lifestyle Medicine (IGLM)

Based on the evidence reviewed, we propose a three-stage IGLM framework for integrating imaging biomarkers into lifestyle medicine practice (Table 1).

Stage	Purpose	Recommended Modalities	Timepoint
1. Baseline Risk Stratification	Identify organ-specific disease burden and set treatment targets	FibroScan (or MRI-PDFF if available) + CACS (if intermediate CV risk) + DXA (BMD + ALMI)	Before intervention
2. Intervention Monitoring	Detect early response; adjust intervention intensity and composition	MRI-PDFF (if MASLD present) + cIMT + point-of-care muscle US	3–6 months
3. Outcome Assessment	Confirm sustained structural change; guide long-term management	Repeat baseline imaging panel + CT body composition (if clinically indicated)	12–24 months

Table 1. The Imaging-Guided Lifestyle Medicine (IGLM) Framework.

The IGLM framework is designed to be adaptable across clinical settings. In resource-limited environments such as primary care clinics in low- and middle-income countries or universal healthcare systems, the first tier emphasizes modalities that are widely available and cost-effective: ultrasound-based assessments (cIMT, FibroScan, muscle ultrasound) and DXA. In research settings or specialist referral centers, the framework accommodates higher-resolution modalities including MRI-PDFF, MR elastography, HR-pQCT, and CT body composition analysis.

7.3 Multi-organ Intervention Strategy

To address the competing demands identified across the four domains, we recommend an integrated lifestyle prescription incorporating: (1) moderate caloric deficit (500–750 kcal/day below requirements) rather than aggressive restriction, to support gradual weight loss while minimizing bone and muscle loss; (2) protein intake of 1.2–1.6 g/kg/day to support muscle protein synthesis and attenuate exercise-associated bone resorption; (3) combined exercise programming including aerobic training (150 min/week moderate intensity) for cardiovascular and hepatic benefits, progressive resistance training (2–3 sessions/week) for muscle and bone preservation, and weight-bearing impact activities for osteogenic stimulation; and (4) Mediterranean dietary pattern emphasis for its concurrent hepatoprotective, anti-inflammatory, and cardiovascular benefits [11].

7.4 Cost-effectiveness and Feasibility Considerations

The feasibility of implementing the IGLM framework depends on local imaging infrastructure and healthcare financing. In universal healthcare systems, cost-effective point-of-care imaging (ultrasound, FibroScan, DXA) can be integrated into primary care workflows. In systems with capitated or value-based reimbursement models, the upfront cost of baseline imaging may be offset by improved targeting of lifestyle interventions and reduced downstream costs of treating disease complications. Future health economic analyses comparing IGLM-guided care with standard care are needed to quantify this value proposition.

8. Future Directions

Several emerging technologies and research priorities have the potential to substantially advance the integration of imaging with lifestyle medicine.

Artificial intelligence (AI) and deep learning are enabling automated extraction of body composition data from routine clinical imaging. Fully automated deep learning tools for sarcopenia assessment from CT scans have already been validated, demonstrating comparable performance to manual segmentation while requiring no additional operator time [29]. Similar AI-driven approaches for automated liver fat quantification from standard abdominal MRI and CT are under active development.

Radiomics—the high-throughput extraction of quantitative features from medical images—offers the possibility of developing multiparametric imaging signatures that could predict individual responses to specific lifestyle interventions. This approach aligns with the broader trend toward precision lifestyle medicine, in which intervention prescriptions are tailored based on individual phenotypic characteristics rather than population-level guidelines.

The integration of continuous wearable sensor data (activity monitors, continuous glucose monitors, sleep trackers) with serial imaging assessments could create a rich longitudinal dataset linking daily behavioral patterns to objective organ-level outcomes. This data fusion approach would enable more granular understanding of dose-response relationships between specific behaviors and imaging-measured changes.

Finally, there is an urgent need for consensus on standardized imaging endpoints for lifestyle medicine clinical trials. In oncology, the RECIST criteria provide a universal framework for imaging-based treatment response assessment. An analogous standardization effort for lifestyle medicine—specifying the modality, protocol, measurement site, analytical approach, and threshold for clinically meaningful change for each imaging biomarker—would greatly facilitate comparability across studies and accelerate evidence synthesis.

9. Conclusion

This narrative review demonstrates that radiologic biomarkers can provide objective, reproducible, and organ-specific evidence that lifestyle interventions are capable of reversing or decelerating disease progression across multiple organ systems. MRI-PDFF for hepatic steatosis, cIMT for subclinical atherosclerosis, DXA for bone mineral density, and CT-based skeletal muscle analysis for sarcopenia each offer validated, clinically relevant endpoints that respond to behavioral interventions over timeframes of 3–24 months.

The proposed IGLM framework provides a practical, tiered approach for integrating these imaging biomarkers into both clinical practice and research trial design. By monitoring multiple organ systems simultaneously, clinicians can identify and manage the competing

demands inherent in comprehensive lifestyle interventions—particularly the tension between weight loss for metabolic benefit and preservation of bone and muscle integrity.

To advance this field, standardized imaging protocols specifically designed for behavioral intervention trials are needed, along with health economic analyses of imaging-guided versus standard lifestyle medicine care. The convergence of AI-enabled automated image analysis, wearable sensor technology, and precision medicine approaches creates unprecedented opportunities to make imaging-guided lifestyle medicine both scalable and personalized.

References

1. Lianov L, Johnson M. Physician competencies for prescribing lifestyle medicine. JAMA. 2010;304(2):202–203.
2. World Health Organization. Non-communicable diseases. WHO Fact Sheet. Available at: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases. Accessed 2025.
3. Tang A, Tan J, Sun M, et al. Nonalcoholic fatty liver disease: MR imaging of liver proton density fat fraction to assess hepatic steatosis. Radiology. 2013;267(2):422–431.
4. Idilman IS, Aniktar H, Idilman R, et al. Hepatic steatosis: quantification by proton density fat fraction with MR imaging versus liver biopsy. Radiology. 2013;267(3):767–775.
5. Loomba R, Neuschwander-Tetri BA, Sanyal A, et al. MRI and MRE for non-invasive quantitative assessment of hepatic steatosis and fibrosis in NAFLD and NASH: clinical trials to clinical practice. J Hepatol. 2016;65(5):1006–1016.
6. Stine JG, Munaganuru N, Engstrom A, et al. Change in MRI-PDFF and histologic response in patients with nonalcoholic steatohepatitis: a systematic review and meta-analysis. Clin Gastroenterol Hepatol. 2021;19(11):2274–2283.e5.
7. Vilar-Gomez E, Martinez-Perez Y, Calzadilla-Bertot L, et al. Weight loss through lifestyle modification significantly reduces features of nonalcoholic steatohepatitis. Gastroenterology. 2015;149(2):367–378.e5.
8. Koutoukidis DA, Astbury NM, Tudor KE, et al. Association of weight loss interventions with changes in biomarkers of nonalcoholic fatty liver disease: a systematic review and meta-analysis. JAMA Intern Med. 2019;179(9):1262–1271.
9. Stine JG, DiJoseph K, Pattison Z, et al. Exercise training is associated with treatment response in liver fat content by magnetic resonance imaging independent of clinically significant body weight loss in patients with nonalcoholic fatty liver disease: a systematic review and meta-analysis. Am J Gastroenterol. 2023;118(7):1204–1213.
10. Stine JG, Long MT, Engstrom BI, et al. Physical activity and nonalcoholic fatty liver disease: a roundtable statement from the American College of Sports Medicine. Med Sci Sports Exerc. 2023;55(9):1717–1726.
11. Romero-Gómez M, Zelber-Sagi S, Trenell M. Treatment of NAFLD with diet, physical activity and exercise. J Hepatol. 2017;67(4):829–846.
12. van den Oord SC, Sijbrands EJ, ten Kate GL, et al. Carotid intima-media thickness for cardiovascular risk assessment: systematic review and meta-analysis. Atherosclerosis. 2013;228(1):1–11.
13. Polak JF, O'Leary DH. Carotid intima-media thickness as surrogate for and predictor of CVD. Glob Heart. 2016;11(3):295–312.e3.

14. Lorenz MW, Gao L, Ziegelbauer K, et al. Predictive value for cardiovascular events of common carotid intima media thickness and its rate of change in individuals at high cardiovascular risk—results from the PROG-IMT collaboration. PLoS One. 2018;13(4):e0191172.
15. Grundy SM, Stone NJ, Bailey AL, et al. 2018 AHA/ACC/AACVPR guideline on the management of blood cholesterol. Circulation. 2019;139(25):e1082–e1143.
16. Park JB, Avolio A. Arteriosclerosis and atherosclerosis assessment in clinical practice: methods and significance. Pulse. 2023;11(1):1–8.
17. Ornish D, Brown SE, Scherwitz LW, et al. Can lifestyle changes reverse coronary heart disease? The Lifestyle Heart Trial. Lancet. 1990;336(8708):129–133.
18. Ornish D, Scherwitz LW, Billings JH, et al. Intensive lifestyle changes for reversal of coronary heart disease. JAMA. 1998;280(23):2001–2007.
19. Kadoglou NP, Iliadis F, Liapis CD. Exercise and carotid atherosclerosis. Eur J VascEndovasc Surg. 2008;35(3):264–272.
20. Heffernan KS, Jae SY, Fernhall B. Six months of lifestyle intervention reduces carotid intima-media thickness in African American adults. Hypertension. 2012;60(Suppl 1):A128.
21. Sung KC, Yoo TK, Lee MY, et al. Physical activity and progression of coronary artery calcification in men and women. JAMA Cardiol. 2024;9(7):659–666.
22. van Rosendael AR, van den Hoogen IJ, Gianni U, et al. Association of statin treatment with progression of coronary atherosclerotic plaque composition. JAMA Cardiol. 2021;6(11):1257–1266.
23. Kanis JA, Cooper C, Rizzoli R, et al. European guidance for the diagnosis and management of osteoporosis in postmenopausal women. Osteoporos Int. 2019;30(1):3–44.
24. Kemmler W, Shojaa M, von Stengel S, et al. Exercise training and bone mineral density in postmenopausal women: an updated systematic review and meta-analysis of intervention studies with emphasis on potential moderators. Osteoporos Int. 2023;34(7):1145–1178.
25. Zhao Y, Liu X, Zhang Y, et al. Optimal resistance training parameters for improving bone mineral density in postmenopausal women: a systematic review and meta-analysis. J Orthop Surg Res. 2025;20:487.
26. Shojaa M, von Stengel S, Schoene D, et al. Effects of different types of exercise on bone mineral density in postmenopausal women: a systematic review and meta-analysis. Calcif Tissue Int. 2020;107(5):409–439.
27. Paris MT, Mourtzakis M, Day A, et al. Approaches to assessment of muscle mass and myosteatosis on computed tomography: a systematic review. J GerontolA Biol Sci Med Sci. 2020;75(6):1099–1108.
28. Martin L, Birdsell L, Macdonald N, et al. Cancer cachexia in the age of obesity: skeletal muscle depletion is a powerful prognostic factor, independent of body mass index. J Clin Oncol. 2013;31(12):1539–1547.
29. Pickhardt PJ, Perez AA, Garrett JW, et al. Fully automated deep learning tool for sarcopenia assessment on CT: L1 versus L3 vertebral level muscle measurements for opportunistic prediction of adverse clinical outcomes. AJR Am J Roentgenol. 2022;218(1):124–131.
30. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019;48(1):16–31.
31. Sayers SP. Exercise interventions for the management of sarcopenia: possibilities and challenges. J Frailty Sarcopenia Falls. 2023;8(3):128–139.
32. Boutin RD, Kaptuch JM, Bateni CP, et al. The effect of computed tomography parameters on sarcopenia and myosteatosis assessment: a scoping review. J Cachexia Sarcopenia Muscle. 2023;14(1):87–100.

488
489