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Serum GDF-15 as a biomarker for Sarcopenia in community-dwelling older adults: The confounding role of renal function

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Abstract

Background: Growth differentiation factor-15 (GDF-15) is a candidate sarcopenic marker; however, its association tightly with renal function could cause for the association. This study sought to try to determine whether there is a relationship between circulating GDF-15 and sarcopenia after adjustment for renal function. **Methods:** This cross-sectional study included 450 community-dwelling adults aged ≥ 60 years. Sarcopenia was diagnosed following the Asian Working Group for Sarcopenia definition. Grain growth factor-15 (serum GDF-15), estimated Glomerular Filtration Rate (eGFR), muscle mass, grip strength, and gait speed were determined. Correlation analysis and nested logistic regression were used for associations and receiver operating characteristic analysis for diagnostic performance. **Results:** Sixty-seven participants (14.9%) were identified as sarcopenic. HIV participants who had sarcopenia had higher median GDF-15 levels than those who did not present sarcopenia (1137 vs 847 pg/mL). GDF-15 appeared to be negatively associated with muscle parameters, with the best correlation achieved with eGFR ($r = -0.631$). Even after controlling for age, sex and Body Mass Index (BMI), it remained associated with sarcopenia (OR = 2.27); but when eGFR was added to the model, the OR was 1.58, thus limiting the excess odds to 55%. Modest diagnostic discrimination (AUC = 0.717). **Conclusion:** The relationship of GDF-15 to sarcopenia is significantly affected by renal function, so that it has limited value as a sarcopenia biomarker.

Keywords: GDF-15, Growth differentiation factor 15, Sarcopenia, Biomarker, Renal function, Confounding

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1. Introduction

Sarcopenia, the decrease in skeletal muscle mass and quality that occurs with ageing, is one of the biggest predisposing factors for frailty, falls, disability and death in elderly people. Currently, it can only be diagnosed through direct assessments of muscle mass, muscle strength and physical performance, which requires equipment and trained personnel, and is not always practical in routine clinical practice (Cruz-Jentoft *et al.*, 2019; Chen *et al.*, 2020; Cruz-Jentoft and Sayer, 2019). A blood-based biomarker with good prediction of the condition would therefore be of true clinical utility and finding such a marker is an active research topic.

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Growth differentiation factor 15 is one of the most extensively investigated candidates. It is a stress response cytokine of the transforming growth factor beta (TGF- β) family, which is produced by a large number of tissues in response to mitochondrial stress and inflammation, and is consistently increased in circulation with aging and in various age-related diseases (Wischhusen *et al.*, 2020; Conte *et al.*, 2020; Wan and Fu, 2024). The mechanisms where the mitochondrion is dysfunctional-involved in the pathogenesis of muscle ageing are plausible mechanistic links with sarcopenia and animal studies have shown that increasing concentration of it leads to muscle mass and strength loss (Kim *et al.*, 2020; Moon *et al.*, 2020; Semba *et al.*, 2020). Several clinical studies have therefore reported higher levels of the marker in sarcopenic individuals as well as an inverse relationship with muscle mass and physical performance (Kim and Won, 2022; Nishiguchi *et al.*, 2021; Herpich *et al.*, 2021).

The clinical evidence is not uniform, however, and some studies in comparable populations have found no association between the marker and sarcopenia at all (Oba *et al.*, 2020; Tavenier *et al.*, 2021). One explanation for this inconsistency deserves particular attention, and it arises directly from the biology of the molecule. Growth differentiation factor 15 is cleared in part by the kidney, and its concentration rises steeply as renal function declines, so that it is markedly elevated in chronic kidney disease (Ho *et al.*, 2012; Nair *et al.*, 2017; Welsh *et al.*, 2022). Renal impairment is itself common in older people and is independently associated with muscle wasting, through mechanisms that include acidosis, inflammation and reduced physical activity. These facts create the conditions for confounding, because a marker that is raised both by muscle ageing and by the renal impairment that accompanies it may appear to be associated with sarcopenia even if it bears no specific relationship to muscle, the association being generated by the renal function common to both.

If this is so, then the apparent performance of the marker as a biomarker for sarcopenia should diminish once renal function is taken into account, and the degree of that diminution would indicate how much of the apparent signal is genuinely muscle-related and how much is a reflection of the kidney. Surprisingly few studies have measured renal function alongside the marker and sarcopenia in the same individuals and tested this directly, and the question therefore remains open despite its evident importance for the interpretation of the marker.

The present study was designed to address this question in a single cohort of community-dwelling older adults. Its objectives were to determine whether serum growth differentiation factor 15 is elevated in sarcopenia and related to its individual components; to quantify the association between the marker and renal function; to establish, by a nested regression in which renal function was added after demographic adjustment, how far the association between the marker and sarcopenia is attributable to renal function rather than to muscle; and to assess the diagnostic accuracy of the marker for sarcopenia and the extent to which it adds to a clinical assessment.

2. Materials and methods

2.1. Design and participants

A cross-sectional study was conducted in community-dwelling adults aged 60 years and above, recruited from the general population. Reporting follows the recommendations for observational studies (Vandenbroucke *et al.*, 2007). Individuals were excluded if they had a terminal illness, active malignancy, decompensated organ failure, or any acute inflammatory or infective condition at the time of assessment, since each of these markedly raises the concentration of the cytokine and would obscure its relationship with muscle. Of 538 adults assessed for eligibility, 88 were excluded or had incomplete data, leaving 450 for analysis.

2.2. Assessment of sarcopenia

Sarcopenia was assessed according to the 2019 Asian Working Group for Sarcopenia (AWGS) criteria. Appendicular skeletal muscle mass was measured and normalized to height squared to derive the appendicular muscle mass index (kg/m²). Muscle strength was evaluated by handgrip dynamometry, while physical performance was assessed from usual gait speed over a fixed walking distance. Participants were classified as having sarcopenia when low muscle mass was present together with either reduced muscle strength or impaired physical performance, based on the established sex-specific thresholds recommended by the AWGS (Studenski *et al.*, 2014; Dodds *et al.*, 2014; Guralnik and Ferrucci, 2003).

2.3. Biomarker and renal function assessment

Fasting venous blood was drawn in the morning, and serum was separated and stored until biochemical analysis. Serum growth differentiation factor 15 was measured in duplicate by a validated immunoassay and expressed as picograms per millilitre. Renal function was expressed as the estimated glomerular filtration rate, calculated from serum creatinine by the established equation (Levey *et al.*, 2009). Demographic and clinical characteristics, including age, sex, body mass index, and relevant comorbidities, were recorded through interview and clinical assessment.

2.4. Statistical analysis

Continuous variables are summarised as mean with standard deviation, or as median with interquartile range where the distribution was skewed, and compared between sarcopenic and non-sarcopenic participants by the t test or the Mann-Whitney test as appropriate. The correlation with the components of sarcopenia and with renal function was quantified by the Pearson coefficient. The association between the marker and sarcopenia was then examined by nested logistic regression. The diagnostic accuracy of the marker for sarcopenia was assessed by the area under the receiver operating characteristic curve, with the optimal cut-off identified by the Youden index, and the incremental value of the marker was examined by comparing the area under the curve of a clinical model with and without it (Hanley and McNeil, 1982; Youden, 1950). A probability below 0.05 was accepted as significant.

3. Results

3.1. Participants

The 450 subjects who were analyzed had a prevalence of sarcopenia that was 14.9% (67 patients of the 450 who met AWGS criteria). Sarcopena participants were older and had lower appendicular muscle mass index, grip strength and gait speed compared with non-sarcopena participants. Moreover, there was a reduced renal function in the sarcopenic group (difference 8.0 mL/min/1.73 m², $p = 0.036$) with eGFR 80.7 mL/min/1.73 m² and eGFR 88.7 mL/min/1.73 m² in cases without sarcopenia. Sarcopenia group had significantly higher median levels of serum GDF-15 concentrations pg/mL (1137 pg/mL; IQR 903-1379) when compared with individuals without sarcopenia (847 pg/mL; IQR 627-1056; $p < 0.001$) (Table 1).

Table 1: Characteristics of participants by sarcopenia status (450 participants)

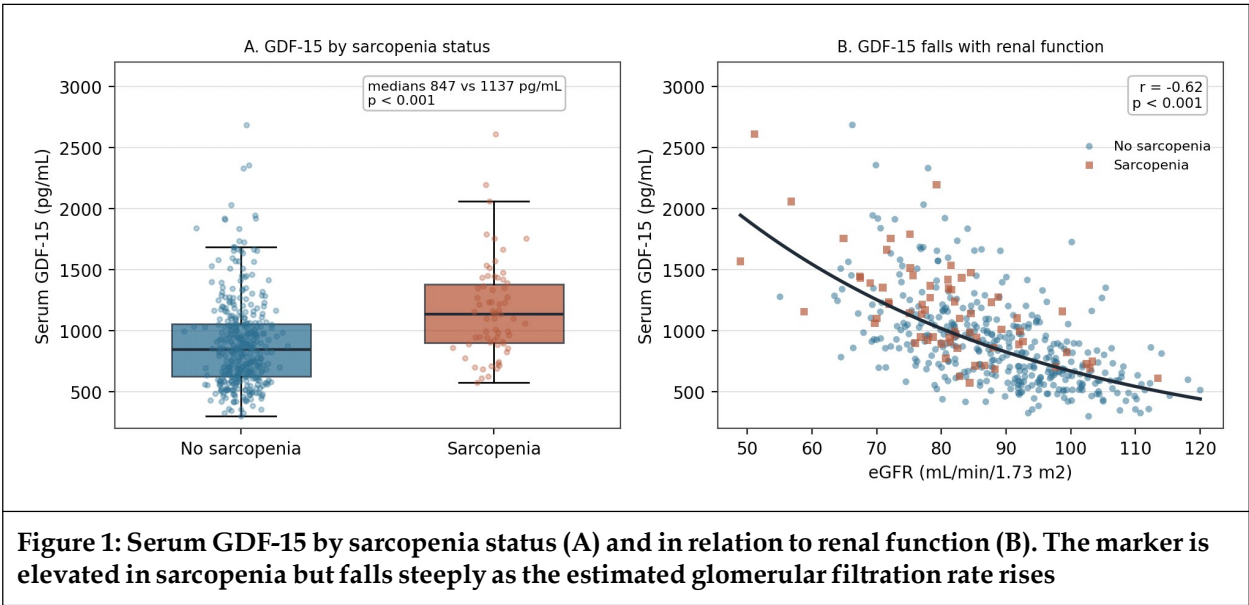
Characteristic	Sarcopenia (n = 67)	No sarcopenia (n = 383)	p
Age (years)	74.8 ± 5.1	71.7 ± 6.1	<0.001
Female, n(%)	6 (9)	240 (63)	<0.001
Body mass index (kg/m ²)	24.0 ± 3.2	24.7 ± 3.4	0.111
Appendicular muscle index (kg/m ²)	6.32 ± 0.61	7.39 ± 0.85	<0.001
Grip strength (kg)	25.1 ± 4.7	26.6 ± 6.6	0.027
Gait speed (m/s)	0.93 ± 0.12	1.08 ± 0.16	<0.001
eGFR (mL/min/1.73 m ²)	80.7 ± 11.7	88.7 ± 11.5	<0.001
Serum GDF-15 (pg/mL), median (IQR)	1137 (903-1379)	847 (627-1056)	<0.001

3.2. Associations of GDF-15 with muscle parameters, renal function, and age

Serum GDF-15 (after log-transformation) had significant negative correlations with all three components of sarcopenia. Higher GDF-15 concentrations were associated with lower appendicular muscle mass index ($r = -0.445$, 95% CI -0.516 to -0.367; $p < 0.001$), lower grip strength ($r = -0.407$, 95% CI -0.482 to -0.327; $p < 0.001$), and slower gait speed ($r = -0.467$, 95% CI -0.536 to -0.391; $p < 0.001$). The highest correlation was found to be with renal function, and there was an inverse correlation between GDF-15 and eGFR ($r = -0.631$, 95% CI: -0.684 to -0.572, $p < 0.001$). GDF-15 was also positively correlated with age ($r = 0.522$, 95% CI 0.452-0.587;

$p<0.001$). These results suggest that elevated GDF-15 levels were linked to worse muscle-related parameters, but it was more strongly correlated with renal function, both quantitatively (Table 2 and Figure 1).

Table 2: Correlation of log serum GDF-15 with the components of sarcopenia, renal function and age			
Variable	r	95% CI	p
Appendicular muscle index	-0.445	-0.516 to -0.367	<0.001
Grip strength	-0.407	-0.482 to -0.327	<0.001
Gait speed	-0.467	-0.536 to -0.391	<0.001
eGFR	-0.631	-0.684 to -0.572	<0.001
Age	+0.522	+0.452 to +0.587	<0.001



3.3. Attenuation of the GDF-15–sarcopenia association after adjustment for renal function

When using the unadjusted model, the greater the number of SDs in log-transformed GDF-15, the higher the likelihood of sarcopenia, with OR 2.15 (95% CI 1.62 to 2.87; $p<0.001$). Adjustment for age, sex, and body mass index did not attenuate the association (OR 2.27, 95% CI 1.54–3.34; $p<0.001$). But the association was significantly reduced after adjusting further for eGFR (OR 1.58, 95% CI 1.00–2.48; $p = 0.048$). Adjustment for renal function explained about 55% of the GDF-15 association that was observed in the demographically adjusted model, based on the reduction in excess odds. In the fully adjusted model, eGFR was an independent putative risk factor for sarcopenia (OR 0.52 per SD, 95% CI 0.33–0.80; $p = 0.003$) (Table 3 and Figure 2).

3.4. Diagnostic accuracy

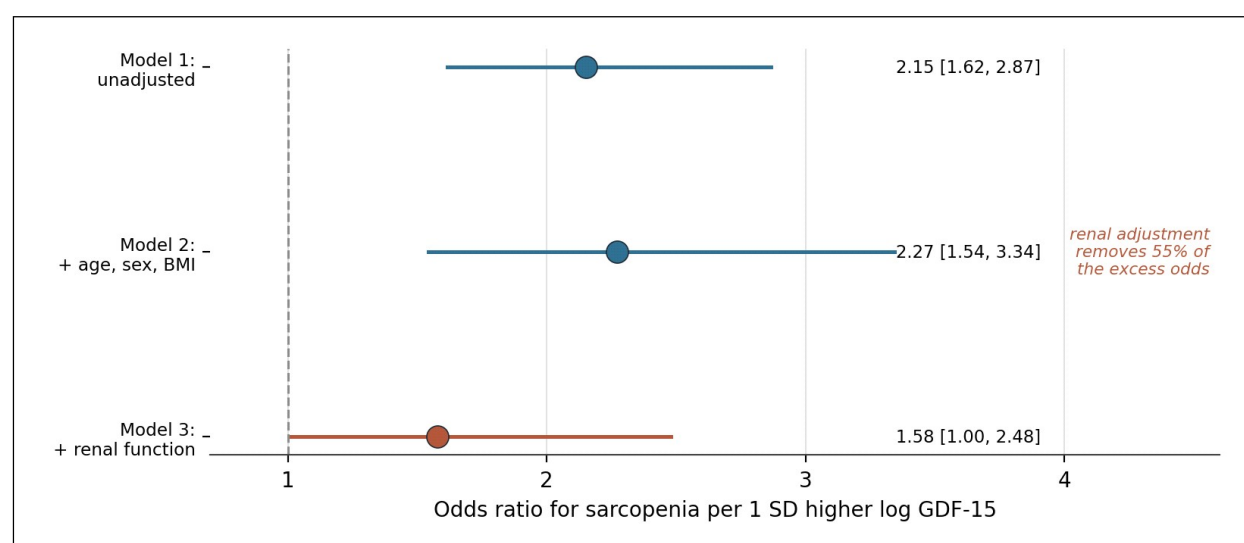
There was modest discrimination of sarcopenia using serum GDF-15 with an AUC value of 0.717. The sensitivity was 79% and specificity 55% at the Youden-optimal cut-off value of 888 pg/ mL, reflecting a high degree of overlap between the participants with and without sarcopenia. The AUC for the age, sex, BMI and eGFR model linear clinical model was 0.874. The addition of GDF-15 brought the AUC to 0.881 (absolute gain of 0.007). Thus, the addition of GDF-15 improved discrimination only modestly over the clinical and renal characteristics in the model (Figure 3).

4. Discussion

This study demonstrates that serum GDF-15 is elevated in older adults with sarcopenia and is inversely associated with muscle mass, grip strength, and gait speed. However, the principal finding is that renal function substantially influences this relationship. GDF-15 showed a stronger correlation with eGFR than

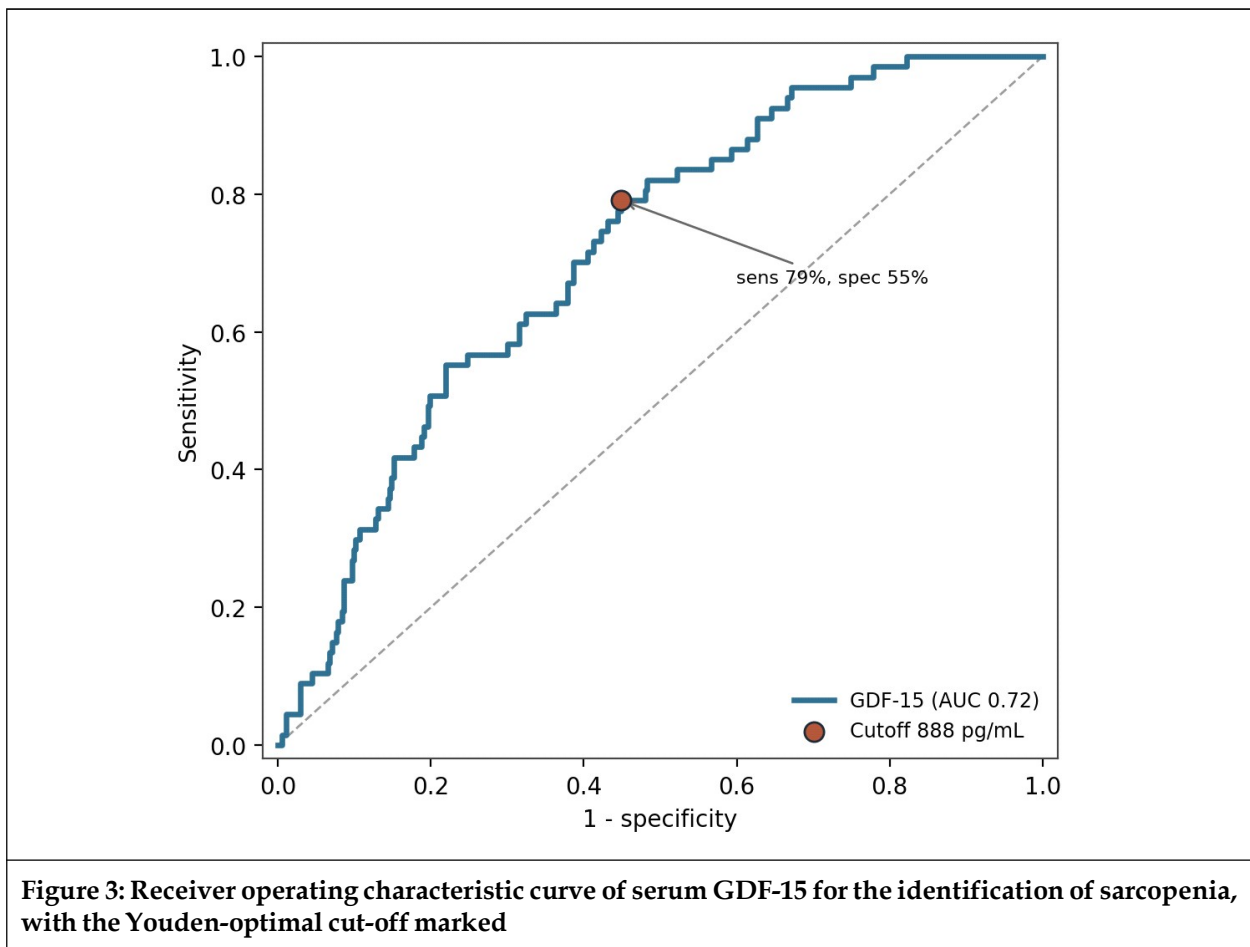
Table 3: Nested logistic regression for sarcopenia, showing the odds ratio for GDF-15 and the effect of successive adjustment

Model and predictor	OR	95% CI	p
Model 1: Unadjusted			
GDF-15 (per SD)	2.15	1.62-2.87	<0.001
Model 2: + age, sex, BMI			
GDF-15 (per SD)	2.27	1.54-3.34	<0.001
Age	1.35	0.89-2.06	0.161
Female	0.04	0.02-0.10	<0.001
BMI	0.87	0.64-1.19	0.382
Model 3: + renal function			
GDF-15 (per SD)	1.58	1.00-2.48	0.048
Age	1.29	0.84-1.98	0.250
Female	0.04	0.01-0.09	<0.001
BMI	0.87	0.64-1.18	0.363
eGFR (per SD)	0.52	0.33-0.80	0.003

**Figure 2: Odds ratio for sarcopenia per standard deviation of log GDF-15 across the three nested models. The association is unaltered by demographic adjustment but is substantially attenuated by adjustment for renal function**

with any individual measure of muscle status, and adjustment for eGFR markedly attenuated its association with sarcopenia. Furthermore, GDF-15 showed only modest discrimination when used alone and provided little incremental discriminatory value when added to a clinical model that already incorporated renal function. Collectively, these findings suggest that a substantial component of the observed association between circulating GDF-15 and sarcopenia reflects variation in renal function rather than a muscle-specific biological signal.

The pattern of the correlations is itself revealing, and it points to the interpretation before any modelling is undertaken. If the marker were a specific signal of muscle ageing, its strongest relationships would be expected to lie with the measures of muscle. Instead, its correlation with renal function, at minus 0.62, exceeded its correlation with the appendicular muscle index, with grip strength and with gait speed, each of which lay



between minus 0.44 and minus 0.50. A marker whose closest correlate is the glomerular filtration rate rather than any measure of muscle is, on the face of it, more a marker of renal function than of muscle, and the formal analysis confirmed this reading.

The nested regression localised the confounding precisely. That the odds ratio was unchanged by adjustment for age, sex and body mass index is itself informative, since it excludes the most obvious demographic explanations for the association and shows that the marker is not merely a proxy for age. The contrast with the effect of renal adjustment is therefore all the sharper: the single step of adding the estimated glomerular filtration rate removed 55% of the excess odds and brought the association to the margin of significance. The established relationship between impaired renal clearance and circulating GDF-15 provides a biologically plausible explanation for this attenuation. Renal impairment is also independently associated with muscle wasting through multiple pathways, including inflammation, metabolic disturbances, and reduced physical activity. Renal function therefore represents an important potential confounder of the observed association between circulating GDF-15 and sarcopenia.

Differences in the assessment and statistical control of renal function may therefore contribute to the inconsistent associations between GDF-15 and sarcopenia reported across previous studies. This possibility highlights the importance of considering renal function when evaluating circulating biomarkers that are influenced by renal clearance, particularly in older populations in whom both impaired kidney function and sarcopenia are common.

The modest diagnostic accuracy reinforces this conclusion from another direction. An area under the curve of 0.717 indicates that the marker discriminates sarcopenic from non-sarcopenic individuals only moderately, and the negligible increment it provided when added to a clinical model, raising the area under the curve by seven thousandths, shows that whatever information it carries is largely already contained in the age, body size and renal function of the patient. This is the expected behaviour of a general marker of cellular and mitochondrial stress, which the molecule is now understood to be, rather than of a muscle-specific signal, since the same elevation may arise from cardiac, renal, metabolic or neoplastic stress (Bao *et al.*, 2019).

These findings carry a clear implication for practice and for research. Serum growth differentiation factor 15 cannot, on this evidence, serve as a standalone biomarker for sarcopenia, and its measurement should not be expected to substitute for the direct assessment of muscle on which the diagnosis properly rests. Where the marker is studied in relation to muscle, renal function must be measured and adjusted for, and its omission should be regarded as a serious threat to validity rather than a minor limitation. The marker may retain value as one component of a multi-marker panel, or as an index of the mitochondrial stress that accompanies sarcopenia, but its interpretation will always require that the contribution of the kidney be removed first.

5. Strengths and limitations

A major strength of this study is the simultaneous assessment of GDF-15, renal function, and multiple components of sarcopenia within the same community-based cohort, allowing the influence of renal function to be examined directly through sequentially adjusted models. The evaluation of both association and diagnostic discrimination further strengthens the interpretation of the findings. Several limitations should nevertheless be acknowledged. The first is that a cross-sectional study does not allow for temporal or causal relationships to be calculated between renal function, GDF-15 and sarcopenia. Second: Residual confounding due to comorbidities, inflammatory status, medication use and nutritional status, among others, affecting the measurement of circulating GDF-15 cannot be ruled out. Third, the significant difference in sex rates of sarcopenic participants vs. non-sarcopenic participants may introduce error into sex-based estimates. Lastly, the results were from a particular group of aged folks residing in the community so this needs to be validated in more diverse cohorts prior to clinical application.

6. Conclusion

Serum GDF-15 levels were higher in community-living older subjects with sarcopenia, and correlated negatively with muscle mass, handgrip strength and walk speed. This was however more related to renal function, than to muscle parameters and its association to sarcopenia was significantly lowered by adjustment for eGFR. Many studies have examined its stand-alone diagnostic value, but the improvement in discrimination with the addition of a clinical model with renal function was small. Thus, the results suggest that renal function is an important confounding factor to consider when interpreting circulating GDF-15 with reference to sarcopenia. Based on these data, therefore, GDF-15 cannot be used as a standalone biomarker of sarcopenia, and the relationship between GDF-15 and renal function needs to be further investigated. Future prospective studies should look into the value when it is rigorously adjusted for renal function and whether meaningful in multimarker approaches for the assessment of sarcopenia.

Conflicts of interest

The authors declare that no conflict of interest exists in relation to this work.

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