The Associations of Psoas and Masseter Muscles With Sarcopenia and Related Adverse Outcomes in Older Trauma Patients- A Retrospective Study

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Abstract

Background: There is an emerging role for the radiological evaluation of the psoas muscle as a marker of sarcopenia, and as a prognostic discriminant in elderly patients with traumatic injuries. Older trauma patients are more likely to undergo cranial than abdomino-pelvic imaging. Identifying sarcopenia using masseter cross sectional area (M-CSA) has shown correlation with mortality. We sought to determine the correlation between psoas: lumbar vertebral index (PLVI) and the M-CSA, and their association with health outcomes.

Methods: Patients aged 65 or above, who presented as a trauma call over a 1 year period were included if they underwent cranial or abdominal CT imaging. Images were retrospectively analyzed to obtain PLVI and mean M-CSA measurements. Electronic records were abstracted for demographics and outcomes. Logistic regression methods, log scale analyses, Cox regression model and Kaplan-Meier plots were used to determine association of sarcopenia with outcomes.

Results: There were 155 eligible patients in the M-CSA group and 204 patients in the PLVI group. Sarcopenia was defined as the lowest quartile in each group. Both PLVI and M-CSA measurements were available in 142 patients. Pearson's correlation indicated a weakly positive linear relationship ($r=0.35$, $p<0.001$) between these. There was no statistical association between M-CSA sarcopenia status and any measured outcomes. Those with PLVI sarcopenia were more likely to die in hospital (adjusted OR 3.38, 95% CI 1.47-9.73, $p=0.006$) and at 2-years (adjusted HR 1.90, 95% CI 1.11-3.25, $p=0.02$). Only 29% patients with PLVI sarcopenia were discharged home, compared with 58% without sarcopenia ($p=0.001$).

Conclusion: Sarcopenia, defined by PLVI, is predictive of increased in-patient and 2- year mortality. Our study did not support prognostic relevance of M-CSA. Further research should be directed at improving the validity of masseter measurements or identifying alternative radiological determinants of sarcopenia on cranial imaging.

Background

Sarcopenia has emerged as a pivotal concept in research and clinical practice due to its correlation with frailty and its association with adverse health outcomes across a spectrum of patient populations. It is defined as "muscle failure" characterised by loss of muscle strength, quality and quantity [1]. A variety of physical performance, anthropometric and diagnostic imaging tools has been used to measure sarcopenia in research and clinical settings [2]. The role of CT imaging to assess muscle composition has gained popularity and is favoured for its routine diagnostic use in many specialties, including surgery, trauma and oncology, with availability greater than other modalities such as magnetic resonance imaging (MRI) and Dual Energy X-ray Absorptiometry (DEXA).

Assessment of sarcopenia using CT in older trauma populations has been associated with increased length of stay [3], in-patient complications [3], mortality at 6 months [4] and 1 year [5] and discharge disposition [6]. Most studies to date have used psoas cross sectional area (P-CSA) to assess for sarcopenia [7]. This relies upon cross-sectional imaging of the abdomen and pelvis. Seventy-five percent of trauma in the elderly involves the head and neck and many older trauma patients have isolated cranio-cervical injuries not always requiring cross-sectional imaging of the abdomen and pelvis [8]. Identifying alternative targets for opportunistic sarcopenia measurement in older trauma is therefore warranted to enable its pragmatic application towards assisting decision-making, prognostication and discharge planning.

In 2016, Wallace et al. published a large retrospective cohort study showing that masseter CSA (M-CSA) correlated with P-CSA as a predictor of 2-year mortality in trauma patients aged above 65 years [9]. They reported that M-CSA was a more robust independent indicator of cumulative 2-year mortality, after adjustment for other variables, compared to P-CSA. Two further studies have been published examining the validity of M-CSA in predicting health outcomes in older patients with traumatic brain injury [10, 11]. Masseter sarcopenia in patients with severe traumatic brain injury has been shown to be predictive of 30-day [10] and 1-year [11] mortality and the need for longer-term acute facilities or rehabilitation on discharge [10].

The primary aim of our study is to determine whether masseter and psoas sarcopenia are associated with mortality up to 2 years in patients aged 65 and older admitted with trauma. Our secondary aims evaluate the association of masseter and psoas sarcopenia with in-hospital outcomes, discharge destination and mortality.

Methods

Subjects and study design

This retrospective cohort study was approved by the Health Research Authority. St. Mary's Hospital is the major trauma centre for North-West London. Our local Trauma and Audit Research Network (TARN) database was used to identify all patients aged 65 years or above who were admitted with suspected traumatic injury over a 1-year period from October 2015-16. Patients who did not sustain any injuries were excluded. A retrospective review and analysis of electronic medical records and imaging was performed.

Sarcopenia quantification

The dependent variables of interest were the M-CSA and the psoas:lumbar vertebral index (PLVI). Measurements were obtained by two radiologists, who were blinded to patient outcomes. Images were analysed using Carestream Picture Archive and Communications System software. Average M-CSA was the mean of measurements on each side deduced from the longitudinal axis 2 cm below the zygomatic arch. This requires reconstructing the imaging plane to align with the proximal and distal attachments. Patients who did not have a CT head or in whom bilateral measurements could not be computed were excluded. P-CSA was measured bilaterally at the level of L4, just below the origin of the posterior elements, and averaged. Height and weight are not always readily available in the hyperacute setting of major trauma. Therefore, to account for the effect of stature on cross sectional area, the ratio of the average P-CSA to the vertebral body CSA at the level of L4 was used. This is the PLVI, a measure of central sarcopenia that has been validated in previous studies [12, 13], including trauma populations [14]. Patients in whom bilateral measurements of P-CSA were not measurable were excluded. Standardised cut-offs for sarcopenia have not been validated; therefore, sarcopenia was defined as M-CSA and PLVI in the lowest quartile in respective patient subgroups.

Outcomes

The primary endpoint was all cause mortality within 2 years of initial presentation to the trauma centre. Patients who had no identifiable registered GP, or who were lost to follow-up were excluded from analysis. Other co-variates recorded were age, injury severity score (ISS), need for intensive care admission, in-patient hospital complications (sepsis, acute kidney injury, myocardial infarction or decompensated heart failure, respiratory failure, venous thrombo-embolism), inpatient mortality, length of stay and discharge destination.

Statistical analysis

Normally distributed data was compared using unpaired t-test; continuous skewed data was compared using the Mann-Whitney test. Values were expressed as the mean and standard deviations, or the median and interquartile ranges, respectively. Categorical comparisons utilised the Chi-squared test or in the case of discharge destination, the Fischer's exact test. Binary outcomes were evaluated using logistic regression analysis and adjusted for age, ISS and gender. Log-scale analysis was used to ascertain differences in length of stay between sarcopenic and non-sarcopenic groups. Differences in outcomes were expressed as odds ratios. Cox regression for survival analysis and Kaplan-Meier curves were used to evaluate association of sarcopenia with survival times over 2 years. Statistical significance was set at $p < 0.05$.

Results

Table I: Exclusion characteristics for patients in masseter & PLVI groups

	Masseter	**PLVI**
Overall CT images (n)	257	241
Exclusion		
Images not visualized/artifact	82 (31.9%)	15 (6.2%)
Unilateral images only	6 (2.3%)	1 (0.4%)
No injury sustained	14 (5.4%)	20 (8.3%)
Statistical outlier	0	1 (0.4%)
Total number in data analysis	**155** (60.3%)	**204 (**84.6%)
No registered GP in UK identified	8	6
Total number in 2 year follow up	**147**	**198**

Sarcopenia based on M-CSA:

One hundered and fifty-five patients met the eligibility criteria including satisfactory visualisation of both masseters (Table I). Thirty-nine patients (lowest quartile) had masseter sarcopenia, with M-CSA of 520 mm^2 or lower. Nearly two-thirds of sarcopenic patients were female (73%, $p < 0.001$). There was no difference in age or injury severity score between the 2 groups (Table II). Eight patients were excluded from 2-year follow up due to missing data, thus 2-year mortality data was available for 147 patients (Table I). There was no statistical association between masseter sarcopenia status and in- hospital complications or length of stay (Table III). No significant differences were observed in 2-year survival or discharge destination between patients with and without masseter sarcopenia (Table III).

Table II: Demographics and discharge destination of patients with and without masseter and PLVI sarcopenia

	Masseters			PLVI		
	Sarcopenia	**No sarcopenia**	**P- value**	**Sarcopenia**	**No sarcopenia**	**P- value**
N	39	116		55	149	
Age (y) (SD)	79.7 ± 7.4	77.0 ± 7.7	0.06	81.8 ± 8.9	76.7 ± 7.1	**< 0.001**
Sex						
Males	14 (36%)	85 (73%)	**< 0.001**	17 (31%)	105 (70%)	**< 0.001**
Females	25 (64%)	31 (27%)	-	38 (69%)	44 (30%)	-
ISS [IQR]	16 [5, 24]	16 [9, 26]	0.16	18 [9, 26]	16 [8, 25]	0.31
Discharge destination						
Home	21(54%)	62 (53%)	1.00	16 (29%)	87 (58%)	**0.001**
Rehab Unit	3 (8%)	8 (7%)	-	4 (7%)	13 (9%)	-
Nursing Home	0 (0%)	1 (1%)		1 (2%)	3 (2%)	
Other hospital	7 (18%)	23 (20%)		16 (29%)	27 (18%)	
Died	8 (21%)	22 (19%)		18 (33%)	19 (13%)	

Table III: Comparison of outcomes between patients with and without masseter sarcopenia

Outcome	Analysis	Sarcopenia (N=39) n (%)	No Sarcopenia (N=116) n (%)	Odds Ratio (#) (95% CI)	P-value
ICU admission	Unadjusted	3 (8%)	21 (18%)	0.38 (0.11, 1.34)	0.13
	Adjusted (*)	-	-	0.41 (0.09, 1.78)	0.23
Respiratory failure	Unadjusted	10 (26%)	35 (30%)	0.80 (0.35, 1.81)	0.59
	Adjusted (*)	-	-	1.03 (0.43, 2.53)	0.95
MI or heart failure	Unadjusted	1 (3%)	4 (3%)	0.74 (0.80, 6.80)	0.79
	Adjusted (*)	-	-	0.49 (0.04, 5.56)	0.57
Acute Kidney Injury	Unadjusted	33 (8%)	13 (11%)	0.66 (0.18, 2.45)	0.54
	Adjusted (*)	-	-	0.63 (0.15, 2.59)	0.52
Venous	Unadjusted	0 (0%)	3 (3%)	(+)	0.57
Thrombosis	Adjusted (*)	-	-	-	-
Sepsis	Unadjusted	4 (10%)	15 (13%)	0.77 (0.24, 2.47)	0.66
	Adjusted (*)	-	-	1.30 (0.36, 4.68)	0.69
Any complication	Unadjusted	15 (38%)	46 (40%)	0.95 (0.45, 2.00)	0.90
	Adjusted (*)	-	-	1.13 (0.50, 2.55)	0.77
In-hospital mortality	Unadjusted	8 (21%)	22 (19%)	1.10 (0.45, 2.73)	0.83
	Adjusted (*)	-	-	1.18	0.35

				(0.56, 5.05)	
Total length of stay (median days & IQR)	Unadjusted	13 [2, 22]	10 [4, 20]	0.94 (0.64, 1.36)	0.73
	Adjusted (*)	-	-	1.07 (0.73, 1.59)	0.72
		(N=38)	**(N=109)**	**Hazard Ratio(#)**	
2 year Survival time	Unadjusted	17	36	1.47 (0.82, 2.61)	0.19
	Adjusted (*)	-	-	1.76 (0.94, 3.31)	0.08

(*) Adjusted for: age, sex, ISS

(#) Calculated as odds of outcome in Sarcopenia group relative to odds in No Sarcopenia group

(+) No occurrences in one category. Analysis using Fisher's exact test

Sarcopenia based on PLVI:

Two hundred and five patients were eligible for analysis (Table I). One patient was excluded as an extreme outlier. Analysis was thus based on data from 204 patients, with a mean PLVI of 0.66 ± 0.19. Fifty-five patients (lowest quartile) who had PLVI values of 0.53 or lower were classified as sarcopenic. Two-year mortality data was available in 198 patients (Table I). There was a statistically significant difference in gender between both groups, with 70% of females being sarcopenic ($p < 0.001$) (Table II). Sarcopenic patients were older, with an average age of 82 years compared to 72 years in the non-sarcopenic group ($p < 0.001$) (Table II). In-hospital mortality was significantly higher in sarcopenic patients (adjusted OR 3.38, 95% CI 1.47–9.73, $p = 0.006$) with 33% of patients with PLVI sarcopenia dying as inpatients compared to 13% of non-sarcopenic patients (Table IV). In hospital complications were similar between groups. Only 29% of patients with PLVI sarcopenia were discharged home, compared to 58% in the non-sarcopenic group ($p = 0.001$) (Table II). Patients with sarcopenia had shorter survival times, as illustrated by Kaplan-Meier survival curves (Figure I). The risk of death up to 2 years after injury in the sarcopenic group was 1.9 times higher after accounting for patient demographics and injury severity (adjusted OR 1.90, 95% CI 1.11–3.25, $p = 0.02$) (Table IV).

Table IV: Comparison of outcomes between patients with and without psoas sarcopenia

Outcome	Analysis	Sarcopenia (N=55) n (%)	No Sarcopenia (N=149) n (%)	Odds Ratio (#) (95% CI)	P-value
ICU admission	Unadjusted	10 (18%)	21 (14%)	1.35 (0.59, 3.09)	0.47
	Adjusted (*)	-	-	1.37 (0.48, 3.93)	0.56
Respiratory failure	Unadjusted	16 (29%)	41 (28%)	1.09 (0.55, 2.14)	0.82
	Adjusted (*)	-	-	1.04 (0.47, 2.28)	0.93
MI or heart failure	Unadjusted	6 (11%)	4 (3%)	4.44 (1.20, 16.4)	**0.03**
	Adjusted (*)	-	-	2.52 (0.55, 11.5)	0.23
Acute Kidney Injury	Unadjusted	5 (9%)	17 (11%)	0.78 (0.27, 2.22)	0.64
	Adjusted (*)	-	-	0.50 (0.15, 1.71)	0.27
Venous Thrombosis	Unadjusted	1 (2%)	4 (3%)	0.67 (0.07, 6.14)	0.72
	Adjusted (*)	-	-	0.50 (0.04, 5.86)	0.58
Sepsis	Unadjusted	8 (15%)	24 (16%)	0.89 (0.37, 2.11)	0.79
	Adjusted (*)	-	-	0.63 (0.23, 1.73)	0.37
Any complication	Unadjusted	25 (45%)	58 (39%)	1.31 (0.70, 2.44)	0.40
	Adjusted (*)	-	-	1.08 (0.52, 2.21)	0.84

In-hospital mortality	Unadjusted	18 (33%)	19 (13%)	3.33 (1.59, 6.98)	**0.001**
	Adjusted (*)	-	-	3.38 (1.47, 9.73)	**0.006**
Total length of stay (days) [median, IQR]	Unadjusted	14 [6, 24]	10 [4, 18]	1.24 (0.90, 1.70)	0.19
	Adjusted (*)	-	-	1.21 (0.85, 1.71)	0.29
		(N=53)	**(N=244)**	**Hazard Ratio (#)**	
2 year Survival time	Unadjusted	25	44	2.19 (1.36, 3.52)	**0.001**
	Adjusted (*)	-	-	1.90 (1.11, 3.25)	**0.02**

(*) Adjusted for: age, sex, ISS

(#) Calculated as odds of outcome in Sarcopenia group relative to odds in No Sarcopenia group

(+) Unable to calculate odds ratios, or perform logistic regression, due to no occurrences in one category. Analysis using Fisher's exact test

Association between M-CSA and PLVI:

One hundred and forty-two patients had both M-CSA and PLVI measurements available. These had a positive linear relationship (Figure II) but the strength of association was weak (Pearson correlation coefficient 0.35, $p < 0.01$). While patients who had masseter sarcopenia were also more likely to have psoas sarcopenia (Table V), discordancy was observed in 23% of the patients.

Table V : Association between Psoas and Masseter sarcopenia definitions using Chi-squared test ($p < 0.001$)

Variable		**Sarcopenia (psoas)**		**Total**
		No	Yes	
Sarcopenia	No	90	16	106
(masseter)	Yes	17	19	36
	Total	107	35	142

Discussion

Our study demonstrates the odds of inpatient mortality is three times higher for older trauma patients with PLVI sarcopenia compared to those without. We also found that PLVI sarcopenia is an independent risk factor for reduced survival two years following injury and is associated with reduced likelihood of being discharged home. Our findings are consistent with several previous studies examining psoas sarcopenia in trauma populations [7].

Correlation between M-CSA and PLVI was weakly positive but M-CSA was not a predictor of overall mortality or any other measured health outcomes in our population. There was no statistical association between sarcopenia defined by either muscle group and inpatient complications or length of stay. Our results contradict findings from other studies that have reported a positive association between M-CSA and mortality at different time points in the trauma population [9–11]. There may be several reasons for this, including differences in measurement of sarcopenia; we defined sarcopenia as the lowest quartiles in masseter and psoas populations regardless of sex. Sarcopenia was more prevalent amongst females in both groups including the PLVI group, in whom we adjusted for body stature. Other studies have defined sarcopenia with sex-based cut-offs below the median [11] or one standard deviation below mean [10]. In our study, the average CSA in patients with masseter sarcopenia was 438.5 ± 49.1 mm^2 in females and 420.7 ± 70.4 mm^2 in males. Two other studies quoted average sarcopenic values as 224 mm^2 [10] and 343 mm^2 [9] in females, and 281 mm^2 [10] and 418 mm^2 [9] in males. This heterogeneity highlights the importance of establishing standardised cut-offs, ideally referenced by healthy, non-hospitalised populations to prevent variations and over-diagnosis.

Additionally, masseter area is associated with variations in dentition status [15], body surface area [15] and craniofacial structure [16]. Similarly, the psoas area may be affected by other comorbidities such as osteoarthritis [17] and spinal disease [18]. A limitation of our study is that due to its retrospective nature, we could not account for indicators of stature, nutrition, dentition, mobility and socioeconomic status. Adjusting for these variables, especially body habitus and stature has relevance in achieving reliable sarcopenia measurements. Height and weight can be easily recorded, but in the acute clinical setting, such as major trauma or emergency surgery, where the clinical application of sarcopenia measurement lies in augmenting emergent decision-making and prognostication, accurate measurements of these variables may not be readily available or feasible. Thus, sarcopenia measurement should ideally rely upon independent predictors of stature that can be measured on the same opportunistic imaging modality. We adjusted for this in our study using the L4 vertebral body CSA as part of the PLVI but we are not aware of an available target for adjustment for stature in masseter sarcopenia quantification.

Furthermore, our results may be impacted by exclusion bias; 34.2% of patients were excluded from statistical analysis due to inadequate visualisation of bilateral masseters, compared with only 6.6% in the PLVI group (Table I). We may have failed to capture patients with reduced muscle quality. M-CSA was measured along the longitudinal axis, which requires reconstructing the imaging plane to align with the proximal and distal attachments. If accurate M-CSA measurement relies on higher quality imaging or is technically more challenging, its viability as a metric for sarcopenia may be limited.

Our study is limited by virtue of its retrospective, single-centre design. We adjusted for injury severity but confounders such as comorbidity index, ethnicity and any operative interventions were not examined. While psoas is the most commonly used muscle group in radiological evaluation of central sarcopenia in the trauma population [7], there is only one other study that looks specifically at PLVI [14]. Conversely, this showed an

association of PLVI with morbidity but not hospital mortality. Differences in PLVI cut-offs and determinants of inpatient morbidity could explain this disparity.

The prospect of muscle segmentation on volumetric CT imaging using deep learning algorithms provides exciting opportunity for further work in this area and may overcome many of the challenges in sarcopenia measurement, improving precision and validity [19, 20]. The trauma population is unique in the challenges it imposes given the heterogeneity of injuries inflicted- in terms of severity, quantity and distribution of affected body areas. This makes prognostication and clinical decision-making more difficult. Given that many patients in a trauma or neurosurgical setting only undergo CT imaging of the head or neck, it is crucial that future studies focus upon cranial as well as abdominal imaging modalities to develop pragmatic clinical applications for opportunistic sarcopenia assessment. Some studies have indicated that morphometric analysis of temporal muscle thickness [21–22] or zygomatic thickness [21] may be suitable craniofacial surrogates of central sarcopenia. Composite analysis of all facial muscles may serve to enhance diagnostic accuracy. Combining sarcopenia as an objective metric with clinical frailty scoring may allow multi-dimensional frailty assessment that can augment prognostication and clinical decision-making. It may serve to identify patients that will benefit most from multi-disciplinary interventions and navigate decision making around procedural interventions, discharge planning and palliation.

Conclusion

This is the first study in a UK elderly trauma population that examines both masseter and psoas muscle groups as indices for sarcopenia and their association with outcome. It provides robust support that older patients with psoas sarcopenia are more likely to die in hospital and at 2 years and are less likely to be discharged to their home environment. Association of masseter sarcopenia with primary or secondary end points did not reach statistical significance. Future studies should include cranial imaging modalities for sarcopenia assessment to enable clinical application to elderly trauma populations

Abbreviations

CT: Computed tomography

CSA: Cross sectional area

DEXA: Dual energy X-ray absorptiometry

ISS: Injury severity score

L4: Lumbar vertebral level 4

M-CSA: Masseter cross sectional area

MRI: Magnetic resonance imaging

P-CSA: Psoas cross sectional area

PLVI: Psoas- Lumbar vertebral index

TARN: Trauma and Audit Research Network

Declarations

Ethics approval & Consent to participate: The study has been approved by the Human Research Authority. No ethical approval was needed and subjects were not contacted, due to its retrospective design.

Consent for publication: Not applicable

Availability of data and material: Datasets generated and analysed are available from corresponding author on reasonable request

Competing interest: The authors declare they have no competing interests

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Authors' contribution:

SV participated in collection of clinical data, data interpretation and manuscript drafting

MSJW participated in conceptualization and design of the study

MN and AS interpreted radiological images to obtain relevant psoas and masseter measurements

HCUO participated in acquisition of clinical data from electronic medical records.

CA participated in study conceptualization and design, and acquisition of relevant clinical data.

MF participated in conceptualization and design of the study and critical appraisal to data

GP is the chief investigator, responsible for conceptualization and design, data interpretation, critical appraisal and manuscript drafting.

All authors were involved in the critical revision and approval of the final manuscript

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Figures

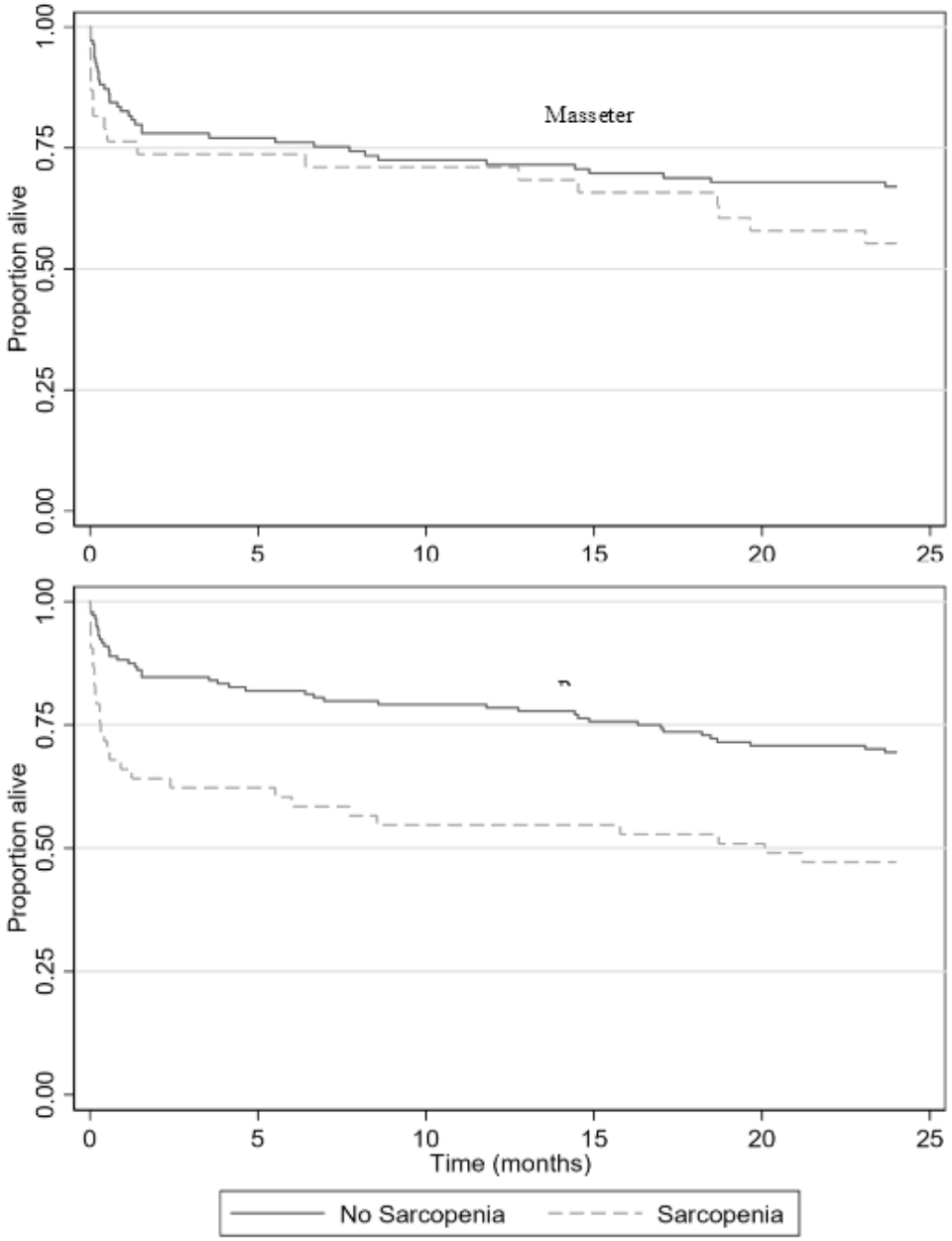

Figure 1

Kaplan-Meier plots of survival in patients with and without masseter (above) and psoas (below) sarcopenia

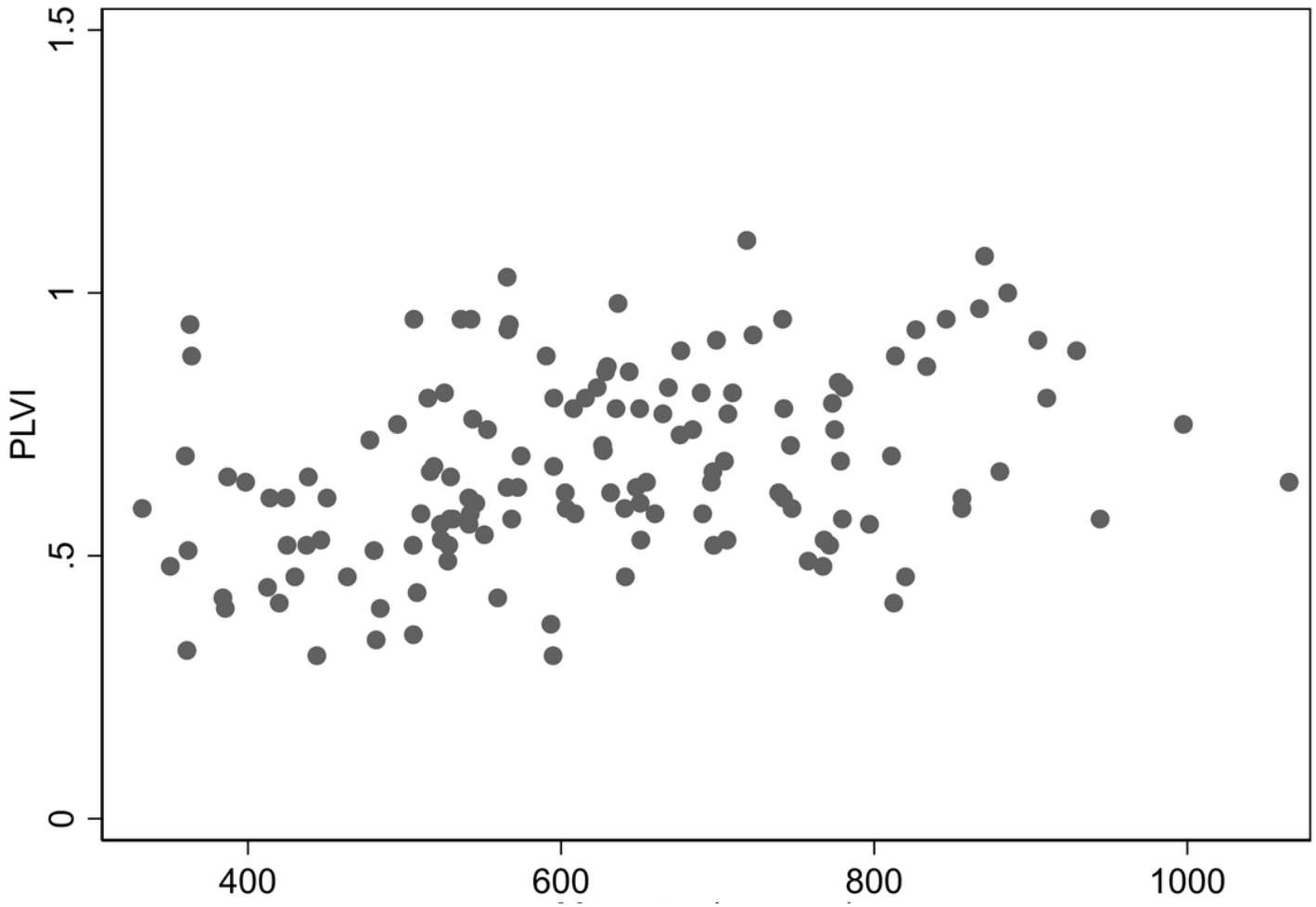

Figure 2

Scatterplot illustrating association of PLVI and Masseter measurements