POSSIBLE SARCOPENIA AND ITS ASSOCIATION WITH GLYCAEMIC CONTROL IN OLDER ADULTS WITH TYPE 2 DIABETES MELLITUS: A HOSPITAL-BASED CROSS-SECTIONAL STUDY

by

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College crest here

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled “Possible sarcopenia and its association with glycaemic control in older adults with type 2 diabetes mellitus: a hospital-based cross-sectional study” is a bonafide and genuine research work carried out by me under the guidance of Dr. Sample Guide, Professor, Department of General Medicine, Sample Medical College, Bengaluru.

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This is a sample thesis, made to show the RGUHS format. Its college, its staff and every person named in it are fictional.

No patient took part in this study: its participants, data and results are invented for illustration, and none of its results may be quoted as evidence.

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List of abbreviations

Abbreviation	Expansion
AUC	Area under the curve
AWGS	Asian Working Group for Sarcopenia
BMI	Body mass index
CI	Confidence interval
DXA	Dual-energy X-ray absorptiometry
HbA1c	Glycated haemoglobin
HPLC	High-performance liquid chromatography
IEC	Institutional Ethics Committee
IPAQ-SF	International Physical Activity Questionnaire, Short Form
IQR	Interquartile range
MET	Metabolic equivalent of task
OR	Odds ratio
PECO	Population, exposure, comparison, outcome
PR	Prevalence ratio
ROC	Receiver operating characteristic
SARC-F	Strength, assistance in walking, rise from a chair, climb stairs, falls
SD	Standard deviation
SGLT2	Sodium-glucose cotransporter 2

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1 Abstract

Title

"Possible sarcopenia and its association with glycaemic control in older adults with type 2 diabetes mellitus: a hospital-based cross-sectional study"

Background & Objectives

The Asian Working Group for Sarcopenia (AWGS) 2019 defines possible sarcopenia, low muscle strength or low physical performance, as a category that bedside tools can identify. How often it is present in older Indian adults with type 2 diabetes, and whether it is associated with glycaemic control, is uncertain. To estimate the prevalence of possible sarcopenia in adults aged 60 to 75 years with type 2 diabetes, and its association with glycaemic control.

Methods

A hospital-based cross-sectional study of consecutive outpatients at a teaching hospital in Karnataka. Possible sarcopenia followed the AWGS 2019 primary-care algorithm: case-finding by calf circumference or the SARC-F, then low handgrip strength or a slow five-times chair stand. Prevalence was estimated with a Wilson 95% confidence interval (CI); the association with a glycated haemoglobin (HbA1c) of 9% or more was estimated as a prevalence ratio (PR) by modified Poisson regression, adjusted for age, sex, body mass index (BMI), duration of diabetes, physical activity and hypertension, with the odds ratio (OR) alongside.

Results

Of 168 enrolled, 161 were analysed. Possible sarcopenia was present in 85 (52.8%; 95% CI 45.1–60.4), and in 67.7% without the case-finding step. Its prevalence rose from 26.7% at an HbA1c below 7% to 53.7% at 7–8.9% and 67.3% at 9% or more (test for trend $p < 0.001$). The adjusted PR for an HbA1c of 9% or more was 1.41

(95% CI 1.09–1.82), and the adjusted OR 2.78 (1.22–6.36). Handgrip strength correlated inversely with HbA1c (Spearman's ρ = −0.22, 95% CI −0.37 to −0.07).

Interpretation & Conclusion
Possible sarcopenia was common in older adults with type 2 diabetes and was associated with poorer glycaemic control. As a cross-sectional, bedside estimate without muscle mass, it is not a diagnosis of sarcopenia and cannot show which came first; strength is worth assessing in patients with poor glycaemic control.

Keywords
sarcopenia; hand strength; glycated haemoglobin; type 2 diabetes mellitus; aged; cross-sectional studies; India.

2 Introduction

Sarcopenia is the loss of skeletal muscle strength and physical function, with low muscle mass, that accompanies ageing and chronic disease. In Asia its assessment has been standardised by the Asian Working Group for Sarcopenia (AWGS), whose 2019 consensus update set cut-offs for muscle strength and physical performance and described separate pathways for community and hospital settings, each beginning with a case-finding step.[1]

The same update introduced a category of possible sarcopenia: low muscle strength or low physical performance, identified without any measurement of muscle mass, for use in primary health care and community-based health promotion.[1] Its pathway needs only a measuring tape, a short questionnaire, a handgrip dynamometer and a chair. Case-finding is by calf circumference or the SARC-F questionnaire, and a case-found person then has handgrip strength or the five-times chair stand test measured; either a low handgrip strength or a slow chair stand identifies possible sarcopenia, after which lifestyle modification is advised.[2]

Type 2 diabetes mellitus and muscle are closely linked. In the Baltimore Longitudinal Study of Aging, a largely non-diabetic community cohort, knee extensor strength and muscle quality were lower across rising quartiles of glycated haemoglobin (HbA1c) although muscle mass was similar, and the authors suggested that the association may be mediated in part by peripheral neuropathy.[3] In middle-aged Asian outpatients with type 2 diabetes, handgrip strength has been found to correlate inversely with HbA1c.[4]

The Indian evidence is small and inconsistent. A tertiary-care study from Odisha that measured muscle mass by dual-energy X-ray absorptiometry (DXA) found sarcopenia more often in adults with type 2 diabetes than in those without, but no significant association with HbA1c.[5] A hospital-based study from Gujarat, which defined

possible sarcopenia by handgrip strength alone, found it in the large majority of its participants.[6] How often possible sarcopenia is found therefore depends heavily on how the AWGS pathway is applied.

HbA1c is measured routinely in the diabetes clinic, and calf circumference, the SARC-F, handgrip strength and the chair stand can each be completed at the bedside without bioelectrical impedance analysis (BIA) or DXA. This study applies the full AWGS 2019 primary-care pathway, with its case-finding step, to older adults with type 2 diabetes attending the General Medicine outpatient department of a tertiary-care teaching hospital in Karnataka, and asks whether possible sarcopenia identified in this way is associated with glycaemic control.

2.1 Need for the study

Four gaps justify the study.

- **No usable local estimate.** No estimate of possible sarcopenia is available for the older adults with type 2 diabetes who attend this hospital's medical outpatient department. The Indian hospital figure of 89.6% cannot stand in for one: it defined possible sarcopenia by handgrip strength alone, without the case-finding step, and so describes a broader outcome than the full AWGS 2019 pathway.[6]
- **Inconsistent evidence on glycaemic control.** In an Indian study that measured muscle mass by DXA, HbA1c was not associated with sarcopenia,[5] whereas longitudinal data from a largely non-diabetic community cohort link higher HbA1c to lower muscle strength.[3] None of the studies reviewed here related HbA1c to possible sarcopenia identified by the full primary-care pathway.
- **Muscle strength may be the component most closely related to glycaemia.** In the longitudinal data, higher HbA1c went with lower strength and muscle

quality but not with lower muscle mass,[3] and in middle-aged outpatients in Jakarta handgrip strength correlated inversely with HbA1c.[4] Possible sarcopenia is defined by strength and performance, so it may show an association that studies of muscle mass miss.

- **A bedside pathway the outpatient department can use.** The AWGS 2019 primary-care pathway needs no body-composition equipment, and it ends in lifestyle advice that the treating physician can give.[1,2] Knowing how often it is positive, and in whom, tells the department whether to adopt it.

The study therefore set out to estimate the prevalence of possible sarcopenia by the AWGS 2019 primary-care criteria in adults aged 60 to 75 years with type 2 diabetes, and to describe its association with glycaemic control.

3 Objectives

3.1 Research question

In adults aged 60 to 75 years with type 2 diabetes mellitus attending a tertiary-care teaching hospital in Karnataka, what proportion have possible sarcopenia by the AWGS 2019 primary-care criteria, and is possible sarcopenia associated with glycaemic control?

3.2 Framing (PECO)

The study is observational, so its question is framed as PECO, with an exposure in place of an intervention.

Table 1. The research question framed as PECO

Element	This study
Population	Adults aged 60 to 75 years with type 2 diabetes mellitus attending the General Medicine outpatient department of a tertiary-care teaching hospital in Karnataka
Exposure	Exposure: glycaemic control, measured as HbA1c; poor control is HbA1c of 9% or more
Comparison	Participants with better glycaemic control (HbA1c below 9%), and across the three HbA1c categories
Outcome	Possible sarcopenia by the AWGS 2019 primary-care criteria: case-finding by calf circumference or SARC-F, then low handgrip strength or a slow five-times chair stand

3.3 Aim

To study possible sarcopenia, identified with bedside tools only, and its association with glycaemic control in older adults with type 2 diabetes mellitus.

3.4 Objectives

- Primary: to estimate the proportion of adults aged 60 to 75 years with type 2 diabetes who have possible sarcopenia by the AWGS 2019 primary-care criteria, with its 95% confidence interval.
- Secondary (exploratory): to describe the association of possible sarcopenia with glycaemic control (HbA1c category), duration of diabetes and sex, and to estimate the adjusted prevalence ratio of possible sarcopenia for poor glycaemic control (HbA1c of 9% or more), with the odds ratio alongside.

- Secondary (exploratory): to assess the correlation between handgrip strength and HbA1c.
- Secondary (exploratory): to describe how well calf circumference, a surrogate of muscle mass, discriminates participants with low muscle strength or low physical performance (the reference for this analysis), by the area under the receiver operating characteristic (ROC) curve; the two measure different things, so this is not a diagnostic-accuracy estimate.

3.5 Hypotheses

- **Null hypothesis.** The proportion of participants with possible sarcopenia is the same in every HbA1c category.
- **Alternative hypothesis.** The proportion of participants with possible sarcopenia differs between HbA1c categories (two-sided).

4 Review of Literature

4.1 Sarcopenia and the AWGS 2019 consensus

The Asian Working Group for Sarcopenia updated its consensus in 2019. The update keeps muscle strength and physical performance at the centre of assessment: low muscle strength is a handgrip strength below 28 kg in men and below 18 kg in women, and low physical performance includes a five-times chair stand time of 12 seconds or more.[1] It describes separate algorithms for the community and for hospitals, and both begin with case-finding by calf circumference (below 34 cm in men and 33 cm in women), the SARC-F questionnaire (a score of 4 or more) or the combined SARC-CalF.[1]

4.2 Possible sarcopenia in primary care

The most practical change of the 2019 update was the category of possible sarcopenia, defined by low muscle strength or low physical performance alone and intended for primary health care and community-based health promotion.[1] Won, a co-author of the update, sets out the primary-care algorithm step by step: case-finding by calf circumference, measured as the larger of both calves with a non-elastic tape, or by the SARC-F, whose five components give a total score of 10; then handgrip strength or the five-times chair stand; and, on either low result, a diagnosis of possible sarcopenia and advice on lifestyle modification. The algorithm has no gait speed step.[2] Won adds that clinical conditions, diabetes mellitus among them, can take the place of case-finding,[2] a point that matters for any study in which every participant has diabetes.

4.3 Sarcopenia in type 2 diabetes in India

Sravya and colleagues compared 159 adults with type 2 diabetes and 79 without, all over 50 years of age, at a tertiary-care centre in Odisha, using the AWGS 2019 criteria with muscle mass measured by DXA.[5] Sarcopenia was present in 22.5% of

those with diabetes and in 8.86% of those without (p = 0.012).[5] Low body mass index (BMI), low physical activity, hypertension, neuropathy and low serum calcium were associated with sarcopenia, but fasting and postprandial glucose and HbA1c were not.[5]

Yogesh and colleagues studied 404 adults with type 2 diabetes of at least one year's duration (mean age 55 ± 13.5 years) at a tertiary-care hospital in Gujarat.[6] Defining possible sarcopenia by handgrip strength alone, below 28 kg in men and below 18 kg in women, they found it in 89.6% of participants and sarcopenia in 45.3%, and a duration of diabetes over 7 years, against 1 to 3 years, was associated with sarcopenia, with a crude odds ratio of 7.5 (95% confidence interval 3.65–15.4).[6] The contrast between the two studies shows how strongly the estimate depends on the definition used: a strength criterion alone, without case-finding, labels most outpatients with diabetes.

4.4 Glycaemic control and muscle strength

The Baltimore Longitudinal Study of Aging, a largely non-diabetic community cohort, followed 984 participants aged 25 to 96 years, whose HbA1c quartiles ran from below 5.5% to 6.1% or more; knee extensor strength and muscle quality were lower across quartiles of HbA1c ($p < 0.001$), while muscle mass was similar, and the authors suggested that the association may be mediated, at least in part, by peripheral neuropathy.[3] In a cross-sectional study of 133 outpatients with type 2 diabetes aged 40 to 59 years in Jakarta, handgrip strength correlated inversely with HbA1c ($r = −0.24$, $p < 0.01$), a weak correlation that explained little of the variation ($R^2 = 0.06$).[4] The Odisha study, by contrast, found no association between sarcopenia and any glycaemic measure.[5] Neither Indian study reviewed here related possible sarcopenia, identified by the full primary-care pathway with its case-finding step, to HbA1c.

4.5 Choosing the effect measure for a common outcome

When the outcome is common, as possible sarcopenia is expected to be, the odds ratio from logistic regression can strongly overestimate the prevalence ratio, which is the measure of choice in cross-sectional studies. Poisson regression with robust variance estimates the prevalence ratio directly and is a better alternative to logistic regression.[7]

4.6 Measuring physical activity

The International Physical Activity Questionnaire, Short Form (IPAQ-SF), expresses total activity in metabolic equivalent of task (MET) minutes per week, MET-min/week, as 8 × vigorous + 4 × moderate + 3.3 × walking minutes.[8] Across 23 validation studies, its agreement with objective measures was mostly below the acceptable standard and it overestimated activity, so it is a usable but weak measure for adjustment.[8]

5 Material and Methods

5.1 Design and setting

- **Study design.** Analytical hospital-based cross-sectional study: exposure and outcome are measured once, at the same visit, and an association is tested. It estimates a prevalence and cannot establish temporality, so findings are reported as associations only.
- **Setting.** The General Medicine outpatient department of a tertiary-care teaching hospital in Karnataka, South India.
- **Study period.** 18 months from the date of approval by the Institutional Ethics Committee.
- **Sampling.** Consecutive eligible patients attending the outpatient department, until the target sample size is reached.
- **Investigator.** Postgraduate resident, Department of General Medicine.
- **Guide.** Professor, Department of General Medicine.

5.2 Inclusion criteria

- Aged 60 to 75 years.
- Type 2 diabetes mellitus diagnosed at least one year before enrolment.
- Able to stand up and walk without help.
- Written informed consent.

5.3 Exclusion criteria

- Type 1 diabetes, or diabetes secondary to another disease.
- A condition that prevents valid handgrip or chair-stand testing: surgery or injury of the hand, wrist, hip or knee in the past six months; joint pain, or a flare of arthritis in the hands, hips or knees, that prevents maximal effort on either test; stroke with residual weakness; Parkinson's disease; or a lower-limb amputation.

- Bilateral pitting oedema of the legs, for example from heart failure, advanced chronic kidney disease or chronic liver disease.
- A condition in which HbA1c may not reflect glycaemia: severe anaemia (judged clinically; no haemoglobin threshold is set), a known haemoglobinopathy (such as sickle cell disease or thalassaemia) or G6PD deficiency, or a blood transfusion in the past three months.
- Acute illness, or admission to hospital, in the past four weeks.
- Cognitive impairment or psychiatric illness that prevents consent or completing the SARC-F.
- Current systemic glucocorticoid therapy, or a malignancy under active treatment.

Mild or moderate anaemia is not excluded, and iron deficiency anaemia, common in India, may falsely raise HbA1c; haemoglobin is recorded so that HbA1c can be read against it. Severe anaemia is excluded on clinical judgement.

5.4 Why a bedside pathway

AWGS 2019 scopes possible sarcopenia to primary health care and community settings. It is used here because it needs only a tape, a questionnaire, a dynamometer and a chair: the study asks how often this bedside identification is positive in a busy outpatient department without BIA or DXA, not how many patients have a confirmed diagnosis. Possible sarcopenia is the AWGS 2019 category built for such settings,[1] and its algorithm needs no body-composition equipment.[2]

5.5 Measurements

All four measures (calf circumference, SARC-F, handgrip strength and the five-times chair stand) are taken in every participant at the same visit, whatever the case-finding result; the AWGS 2019 algorithm is applied at analysis.

- **Calf circumference.** Measured standing, feet shoulder-width apart, on both calves at the widest part, with a non-elastic tape applied snugly without compressing the muscle; the larger value is recorded, in cm.[2]
- **SARC-F.** The five-item SARC-F questionnaire (strength, assistance in walking, rising from a chair, climbing stairs, falls), with a total score out of 10.[2]
- **Handgrip strength.** A hydraulic handheld dynamometer, seated with the elbow flexed to a right angle; at least two trials with each hand; the maximum value is recorded to the nearest kg, as the dial reads.
- **Five-times chair stand.** Five rises from a straight-backed chair without armrests, seated with feet flat on the floor, arms crossed over the chest and shoes on, timed in seconds; two trials with 60 seconds of rest between them, and the fastest time is used. A participant who could not complete five rises without using the arms was coded as having low physical performance, not as missing, and no time was recorded.
- **HbA1c and haemoglobin.** Glycated haemoglobin (%) by a high-performance liquid chromatography (HPLC) method certified by the National Glycohemoglobin Standardization Program (NGSP), in the hospital laboratory, from a sample taken at the enrolment visit, with haemoglobin from the same sample.
- **Covariates.** Physical activity by the IPAQ-SF, scored as total MET-min/week[8]; peripheral neuropathy from the case file or a 10-g monofilament examination; and current use of metformin, a sodium–glucose cotransporter 2 (SGLT2) inhibitor or insulin from the prescription. Age, sex, the duration of diabetes, known hypertension, weight and height (for BMI) were recorded on the case proforma (Annexures).

5.6 Definitions

The AWGS 2019 cut-offs were applied at analysis to the measurements taken in every participant.[1,2]

Table 2. The AWGS 2019 cut-offs applied at analysis

Step	Measure	Positive when
Case-finding	Calf circumference	Below 34 cm in men, below 33 cm in women
Case-finding	SARC-F	A score of 4 or more, out of 10
Muscle strength	Handgrip strength	Below 28 kg in men, below 18 kg in women
Physical performance	Five-times chair stand	12 s or more, or unable to complete five rises without using the arms

- **Case-finding.** Calf circumference below the sex-specific cut-off, or a SARC-F score at or above its cut-off; either one makes a participant case-found. Both are measured in every participant. This is the case-finding step of the AWGS 2019 algorithm for primary care and community settings. SARC-CalF is not used.
- **Low strength or performance.** Low muscle strength (handgrip strength below the sex-specific cut-off) or low physical performance (a five-times chair stand at or above its cut-off); either one is enough. A participant who cannot complete five rises without using the arms counts as low physical performance, not as missing. Handgrip and the chair stand are measured in every participant; at analysis, possible sarcopenia also requires case-finding. Gait speed is not used.
- **Outcome.** Possible sarcopenia, as defined by the AWGS 2019 primary-care algorithm: case-found, and low handgrip strength or a slow five-times chair stand, applied at analysis to measurements taken in every participant. Muscle mass is not measured, so the study cannot make a confirmed diagnosis and never reports one.
- **Exposure.** Glycaemic control by HbA1c, in three categories: below 7%, 7 to 8.9% and 9% or more; poor control is an HbA1c of 9% or more.

- **Prespecified sensitivity estimate.** The proportion with low handgrip strength, a five-times chair stand at or above its cut-off, or inability to complete five rises without using the arms (coded as low physical performance, not as missing), in all participants, whatever the case-finding result. It shows how much the case-finding step changes the estimate, and corresponds to treating diabetes itself as the trigger for assessment.

5.7 Data collection and quality

Every participant was assessed at one visit by the investigator, using the case proforma in the Annexures. Each proforma was checked for completeness on the day, and the data were entered into a master chart against the participant's serial number. A participant whose proforma remained incomplete was excluded from analysis (a complete-case analysis), and the number excluded and the missing item are reported.

5.8 Ethical considerations

- Approval of the Institutional Ethics Committee was obtained before the first participant was enrolled, and written informed consent was obtained from every participant, in a language the participant understood, after the participant information sheet had been explained.
- The study involved no intervention and no additional blood sample: HbA1c and haemoglobin came from the routine sample of the enrolment visit.
- Participants were identified only by a serial number on the proforma and the master chart; the key linking serial numbers to hospital records was kept separately by the investigator.
- A participant found to have possible sarcopenia was told the result, and the treating physician was informed so that lifestyle advice could be given, as the AWGS 2019 primary-care pathway recommends.[2]

5.9 Statistical analysis

5.9.1 Software and description

Data were entered into a master chart and analysed in Python (pandas, SciPy and statsmodels), with DeLong's method written out in the analysis script. Continuous variables were tested for normality by the Shapiro–Wilk test and summarised as mean and standard deviation (SD) when $p > 0.05$, and as median and interquartile range (IQR) otherwise; categorical variables as number and percentage. Every estimate carries its 95% confidence interval, and a two-sided $p < 0.05$ was taken as statistically significant.

5.9.2 Analysis by objective

- **Prevalence (primary objective).** The prevalence of possible sarcopenia was reported with its Wilson score 95% confidence interval, and the prespecified sensitivity estimate (low strength or performance without the case-finding step) beside it.
- **Possible sarcopenia across groups (exploratory, as are all that follow).** The proportion with possible sarcopenia was compared across the three HbA1c categories, the two duration bands (below 10 years, 10 years or more), sex, hypertension, peripheral neuropathy and each drug by Pearson's chi-square test, or Fisher's exact test (Fisher–Freeman–Halton for more than two groups) when an expected count is below 5, and a linear trend across the ordered HbA1c categories by the Cochran–Armitage test.
- **Continuous variables between groups.** If both groups pass the Shapiro–Wilk test, Student's t-test was used (Welch's when Levene's test shows unequal variances), with the difference in means and its 95% confidence interval; otherwise the Mann–Whitney U test, with the rank-biserial correlation as its effect size.

- **Handgrip strength and HbA1c.** Pearson's or Spearman's correlation, as the Shapiro–Wilk test decides, in all participants and within each sex, because handgrip strength differs by sex; mean handgrip strength was also compared between HbA1c of 9% or more and below 9% within each sex.
- **The adjusted association with poor glycaemic control.** With an outcome this common, the odds ratio overstates the prevalence ratio, so the association of possible sarcopenia with an HbA1c of 9% or more was estimated as a prevalence ratio by modified Poisson regression, with the odds ratio from logistic regression alongside.[7] Model 1, the primary model, adjusts for age, sex, BMI, duration of diabetes, physical activity and hypertension: seven parameters, the exposure included, which gives about 11 events per variable in the smaller outcome group at the planned sample size. Model 2, an exploratory sensitivity model, adds metformin, SGLT2-inhibitor and insulin use, which follow glycaemic control, and peripheral neuropathy, which may lie between hyperglycaemia and lower strength[3]; all four are possible mediators, and with eleven parameters the model has too few events per variable for stable estimates. Haemoglobin and the outcome's components are not adjusted for, and only the exposure's estimates were interpreted.
- **Calf circumference.** The area under the ROC curve of calf circumference (lower counted as positive) against low strength or performance, with its 95% confidence interval by DeLong's method, as a measure of discrimination only.

6 Sample Size

6.1 Basis

The sample size was calculated for the primary objective only, the proportion with possible sarcopenia, estimated to a stated absolute precision. The sample size for estimating a prevalence with a stated absolute precision is $n = z^2 \cdot p(1 - p)/d^2$, where $z = 1.96$ at the 5% level of significance, p is the expected proportion and d is the absolute precision.[9]

6.2 The values chosen

- **Expected proportion, p = 0.5.** No reliable prior estimate exists. The Indian hospital estimate of 89.6% defined possible sarcopenia by handgrip strength alone, without the case-finding step, and so describes a broader outcome than this study's.[6] When no reliable prior estimate is available, $p = 0.5$ is the safe choice: $p(1 - p)$ is largest at 0.5, so it gives the largest sample for the chosen precision.
- **Absolute precision, d = 0.08.** An absolute precision of 8 percentage points, wider than the conventional 5%, chosen so that a single-centre study can reach the sample in the study period; stated as a limitation. An absolute precision of 5% is conventional when the expected prevalence lies between 10% and 90%.[9]
- **Allowance for incomplete proformas.** Dividing by $(1 - 0.10)$, rather than adding 10%, keeps at least 151 analysable participants if 10% of proformas are incomplete.[9]

6.3 Working

$n = 1.96^2 \times 0.5 \times 0.5 / 0.08^2 = 3.8416 \times 0.25 / 0.0064 = 0.9604 / 0.0064 = 150.06$, rounded up to 151. Allowing 10% for incomplete proformas: $151 / (1 - 0.10) = 167.78$, rounded up to 168.

The study therefore planned to enrol 168 participants. The sample size covers the primary objective (the prevalence) only; every association analysis is exploratory and is reported with its 95% confidence interval.

7 Results

7.1 Participants and their characteristics

7.1.1 Participant flow

During the study period, 168 consecutive eligible adults with type 2 diabetes were enrolled. The proformas of 7 were incomplete: the HbA1c report was missing for 3, the SARC-F for 2, the IPAQ-SF for 1 and the handgrip measurement for 1. As planned, they were excluded, and 161 participants with a complete proforma entered every analysis, above the minimum of 151 that the sample size required.

7.1.2 Baseline characteristics

The analysed participants had a median age of 66 years (IQR 63–70; range 60–75), and 91 (56.5%) were men. The median HbA1c was 8.0%, and 49 participants (30.4%) had an HbA1c of 9% or more (Table 3).

Table 3. Characteristics of the analysed participants (n = 161)

Characteristic	Value
Age, years, median (IQR)	66 (63–70)
Men / women, n (%)	91 (56.5) / 70 (43.5)
BMI, kg/m², mean (SD)	25.3 (3.6)
Duration of diabetes, years, median (IQR)	9 (5–14)
Duration of diabetes of 10 years or more, n (%)	80 (49.7)
HbA1c, %, median (IQR)	8.0 (7.2–9.2)
HbA1c below 7%, n (%)	30 (18.6)
HbA1c 7–8.9%, n (%)	82 (50.9)
HbA1c 9% or more, n (%)	49 (30.4)
Haemoglobin, g/dL, mean (SD)	12.9 (1.5)
Physical activity, MET-min/week, median (IQR)	438 (198–891)
Known hypertension, n (%)	100 (62.1)
Peripheral neuropathy, n (%)	52 (32.3)
On metformin, n (%)	137 (85.1)
On an SGLT2 inhibitor, n (%)	46 (28.6)
On insulin, n (%)	38 (23.6)

Mean (SD) when the Shapiro–Wilk test did not reject normality ($p > 0.05$), otherwise median (IQR). IQR, interquartile range; MET, metabolic equivalent of task.

7.2 The AWGS 2019 measurements

7.2.1 Bedside measurements

All four measurements were taken in every analysed participant. Mean calf circumference was 33.4 cm in men and 32.7 cm in women, against case-finding cut-

offs of 34 cm and 33 cm; mean handgrip strength was 27.7 kg in men and 17.3 kg in women, against cut-offs of 28 kg and 18 kg. Five rises without the arms could not be completed by 4 participants (2.5%), who were coded as having low physical performance (Table 4).

Table 4. Bedside measurements (n = 161)

Measurement	Value
Calf circumference in men, cm, mean (SD)	33.4 (2.7)
Calf circumference in women, cm, mean (SD)	32.7 (2.4)
SARC-F score, points, median (IQR)	1 (0–4)
Handgrip strength in men, kg, mean (SD)	27.7 (5.8)
Handgrip strength in women, kg, mean (SD)	17.3 (3.6)
Five-times chair stand, s, median (IQR), in the 157 who completed it	11.8 (10.4–14.0)
Unable to complete five rises without the arms, n (%)	4 (2.5)

7.2.2 The steps of the AWGS 2019 algorithm

Case-finding was positive in 112 participants (69.6%), and low strength or low performance in 109, whatever the case-finding result. Of the 112 case-found participants, 85 also had low strength or low performance and so met the definition of possible sarcopenia (Table 5).

Table 5. Participants positive at each step of the AWGS 2019 primary-care algorithm (n = 161; the rows overlap)

Step	Criterion	n (%)
Case-finding	Calf below 34 cm (men) or 33 cm (women)	96 (59.6)
Case-finding	SARC-F score of 4 or more	47 (29.2)
Case-finding	Either of the two (case-found)	112 (69.6)
Muscle strength	Handgrip below 28 kg (men) or 18 kg (women)	83 (51.6)
Physical performance	Chair stand of 12 s or more, or unable	79 (49.1)
Strength or performance	Either, whatever the case-finding result	109 (67.7)
Outcome	Possible sarcopenia: case-found and low strength or performance	85 (52.8)

7.3 Prevalence of possible sarcopenia

7.3.1 The primary estimate

Possible sarcopenia, by the AWGS 2019 primary-care algorithm, was present in 85 of the 161 participants: a prevalence of 52.8% (95% CI 45.1–60.4, Wilson score interval) (Figure 1A). Both halves of the interval lie within the absolute precision the

sample size was planned for, 8 percentage points (d = 0.08). The prevalence was similar in men and women: 52.7% (48 of 91) and 52.9% (37 of 70) (p = 0.989).

7.3.2 The prespecified sensitivity estimate

When the case-finding step was dropped and every participant with low handgrip strength or low physical performance was counted, the proportion rose to 67.7% (109 of 161; 95% CI 60.1–74.4). The case-finding step therefore lowered the estimate by 14.9 percentage points. Neither figure is a diagnosis of sarcopenia, because muscle mass was not measured.

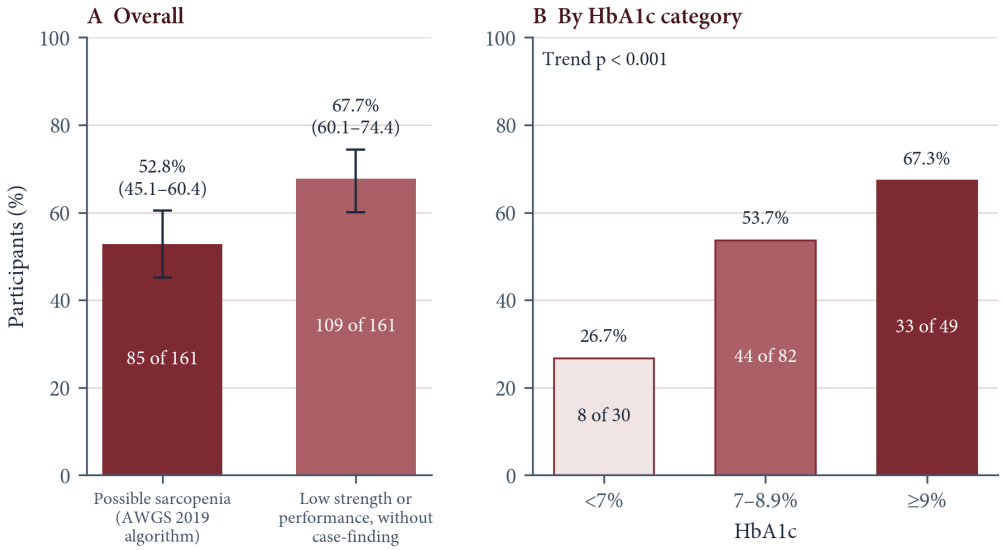

Figure 1 — (A) Prevalence of possible sarcopenia by the AWGS 2019 primary-care algorithm, with its Wilson 95% confidence interval, beside the sensitivity estimate without the case-finding step. (B) Prevalence of possible sarcopenia in each HbA1c category, with the Cochran–Armitage test for trend. Counts inside the bars are participants with the finding, of those in the group.

7.4 Possible sarcopenia across HbA1c categories

7.4.1 Prevalence by HbA1c category

The prevalence of possible sarcopenia rose with each HbA1c category, from 26.7% below 7% to 53.7% at 7–8.9% and 67.3% at 9% or more (Table 6; Figure 1B). The difference across the three categories was statistically significant ($\chi^2 = 12.41$, df = 2, p = 0.002), and the Cochran–Armitage test showed a linear trend (z = 3.42, p < 0.001). Every expected cell count was at least 5 (the smallest was 14.2), so

Pearson's chi-square test was used rather than an exact test. The null hypothesis, that the proportion with possible sarcopenia is the same in every HbA1c category, is therefore rejected.

Table 6. Possible sarcopenia by HbA1c category (n = 161)

HbA1c category	Participants, n	Possible sarcopenia, n (%)
Below 7%	30	8 (26.7)
7–8.9%	82	44 (53.7)
9% or more	49	33 (67.3)
Pearson's χ^2 test	$\chi^2 = 12.41$, df = 2	p = 0.002
Cochran–Armitage test for trend	z = 3.42	p < 0.001

7.4.2 HbA1c in participants with and without possible sarcopenia

Read the other way round, participants with possible sarcopenia had a higher median HbA1c than those without: 8.6% (IQR 7.6–9.6) against 7.7% (6.8–8.7) (Mann–Whitney U = 4,250, p < 0.001; rank-biserial correlation 0.32). HbA1c departed from normality in both groups, hence the rank-based test.

7.5 Adjusted association with poor glycaemic control

7.5.1 The prevalence ratio

Participants with an HbA1c of 9% or more had possible sarcopenia more often than those below 9%: the crude prevalence ratio was 1.45 (95% CI 1.10–1.92). In model 1, the primary model, which adjusted for age, sex, BMI, duration of diabetes, physical activity and hypertension, the prevalence ratio was 1.41 (95% CI 1.09–1.82; p = 0.008) (Table 7). This is the primary estimate of the association: after adjustment, the prevalence of possible sarcopenia among participants with poor glycaemic control was 1.41 times that among the others.

In model 1 the fitted probability exceeded 1 for 10 of the 161 participants, which modified Poisson regression allows; as a check, the prevalence ratio by marginal standardisation from the logistic model with the same covariates was 1.41, the same to two decimals.

7.5.2 The odds ratio alongside

Because possible sarcopenia was common, the odds ratios lay further from 1 than the prevalence ratios (adjusted odds ratio 2.78, 95% CI 1.22–6.36) and overstate the ratio of the two prevalences. They are shown because most published studies report odds ratios.

7.5.3 The exploratory model

Model 2 added four variables that may lie on the pathway between glycaemic control and muscle strength: metformin use, SGLT2-inhibitor use, insulin use and peripheral neuropathy. The prevalence ratio was stable, at 1.44 (95% CI 1.08–1.93). With 6.9 events per variable (computed from the smaller outcome group, the 76 without possible sarcopenia), model 2 is too small to estimate its own coefficients well, and it is read only as a check on model 1.

Table 7. Possible sarcopenia with an HbA1c of 9% or more, against below 9% (n = 161; 85 with possible sarcopenia)

Model	Prevalence ratio (95% CI)	Odds ratio (95% CI)
Crude	1.45 (1.10–1.92); p = 0.009	2.38 (1.18–4.81); p = 0.016
Model 1, primary: adjusted for age, sex, BMI, duration of diabetes, physical activity, hypertension	1.41 (1.09–1.82); p = 0.008	2.78 (1.22–6.36); p = 0.015
Model 2, exploratory: model 1 plus metformin, SGLT2-inhibitor and insulin use and peripheral neuropathy	1.44 (1.08–1.93); p = 0.014	2.96 (1.16–7.60); p = 0.024

Prevalence ratios by modified Poisson regression with robust (sandwich) standard errors; odds ratios by logistic regression, with Wald intervals and p values. Events per variable are computed from the smaller outcome group, the 76 participants without possible sarcopenia: model 1 has 7 parameters besides the intercept and 10.9 events per variable; model 2 has 11 and 6.9, below the conventional 10. Only the estimates for HbA1c are shown: the covariates' own ratios are adjustment terms, not estimates of each covariate's association with possible sarcopenia.

7.6 Handgrip strength and HbA1c

7.6.1 Handgrip strength by glycaemic control

Within each sex, mean handgrip strength was lower in participants with an HbA1c of 9% or more than in those below 9%. The difference in means (9% or more minus below 9%) was −3.6 kg in men (95% CI −6.2 to −1.0; p = 0.007) and −2.1 kg in women (−3.8 to −0.3; p = 0.022) (Table 8).

Table 8. Handgrip strength (kg) by HbA1c, within each sex

Sex	HbA1c 9% or more, mean (SD)	HbA1c below 9%, mean (SD)	Difference (95% CI)	p
Men	25.2 (5.2); n = 26	28.8 (5.8); n = 65	−3.6 (−6.2 to −1.0)	0.007
Women	15.9 (3.0); n = 23	18.0 (3.7); n = 47	−2.1 (−3.8 to −0.3)	0.022

Student's t-test: handgrip strength passed the Shapiro–Wilk test in every group, and Levene's test did not show unequal variances (p = 0.497 in men, p = 0.621 in women). Differences were computed from the unrounded means, so each can differ by 0.1 kg from the difference of the rounded means.

7.6.2 Correlation with HbA1c

Handgrip strength correlated inversely with HbA1c (Spearman's ρ = −0.22, 95% CI −0.37 to −0.07; p = 0.004; n = 161). Because handgrip strength differs by sex, the correlation was also examined within each sex, where it held: ρ = −0.31 in men (95% CI −0.49 to −0.11; p = 0.003; n = 91) and ρ = −0.29 in women (−0.49 to −0.05; p = 0.016; n = 70) (Figure 2). Spearman's rank correlation was used because HbA1c departed from normality; its intervals use the Bonett–Wright standard error.

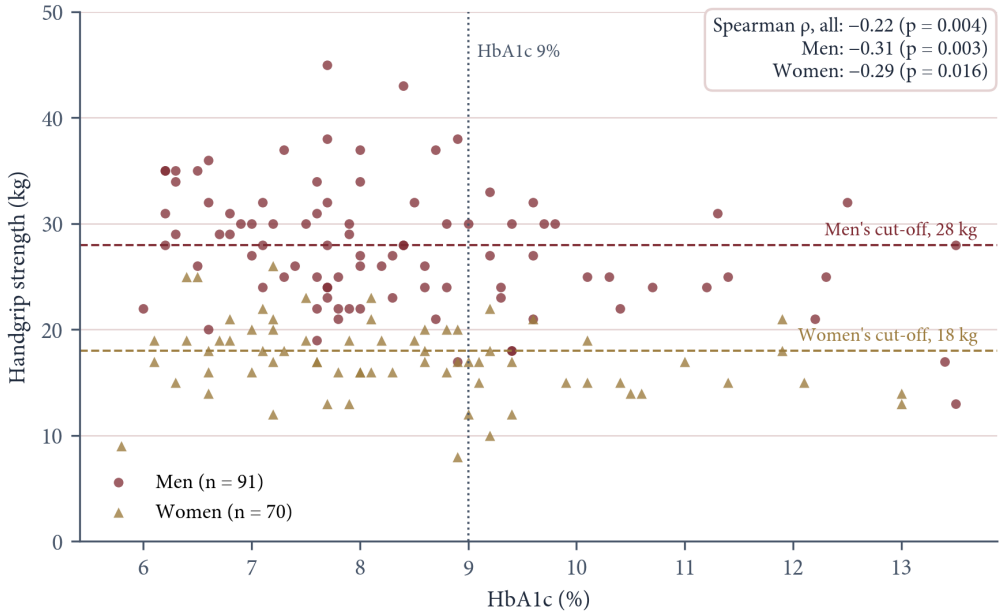

Figure 2 — Handgrip strength against HbA1c in the analysed participants, men and women marked separately, with each sex's AWGS 2019 cut-off for low handgrip strength (dashed) and an HbA1c of 9% (dotted).

7.7 Characteristics with and without possible sarcopenia

7.7.1 Continuous characteristics

Participants with possible sarcopenia were older, had a lower BMI and reported less physical activity than those without; duration of diabetes and haemoglobin did not differ clearly (Table 9).

Table 9. Continuous characteristics by possible sarcopenia

Characteristic	Possible sarcopenia (n = 85)	No possible sarcopenia (n = 76)	Effect size	Test; p
Age, years, median (IQR)	68 (64–71)	65 (62–67)	r = 0.30	Mann–Whitney; 0.001
BMI, kg/m², mean (SD)	24.1 (3.3)	26.7 (3.3)	−2.7 (−3.7 to −1.6)	Student's t; <0.001
Duration of diabetes, years, median (IQR)	10 (5–15)	9 (5–12)	r = 0.10	Mann–Whitney; 0.252
Haemoglobin, g/dL, median (IQR)	13.0 (11.6–13.9)	12.8 (12.2–14.2)	r = −0.10	Mann–Whitney; 0.276
Physical activity, MET-min/week, median (IQR)	396 (132–792)	578 (297–915)	r = −0.22	Mann–Whitney; 0.018

The test for each row follows the Shapiro–Wilk result in the two groups. Effect size: for a Mann–Whitney comparison, the rank-biserial correlation r, positive when the value tends to be higher with possible sarcopenia; for BMI, the difference in means (possible sarcopenia minus none) with its 95% CI, computed from the unrounded means, so it can differ by 0.1 from the difference between the rounded means shown. Medians and quartiles of variables recorded in whole units are rounded to the unit.

7.8 Possible sarcopenia by clinical characteristics

7.8.1 Categorical characteristics

Possible sarcopenia was more common in participants with peripheral neuropathy than in those without (67.3% against 45.9%; p = 0.011). It was also more common in participants on insulin, but that difference was compatible with chance (p = 0.066). There was no clear difference by sex, duration of diabetes, hypertension, metformin use or SGLT2-inhibitor use (Table 10). These are unadjusted, exploratory comparisons that describe the sample; they are not estimates of independent associations.

Table 10. Possible sarcopenia by categorical characteristics

Characteristic	Participants, n	Possible sarcopenia, n (%)	χ^2; p
Men	91	48 (52.7)	0.00; 0.989
Women	70	37 (52.9)	
Diabetes for less than 10 years	81	39 (48.1)	1.41; 0.235
Diabetes for 10 years or more	80	46 (57.5)	
Hypertension	100	52 (52.0)	0.07; 0.796
No hypertension	61	33 (54.1)	
Peripheral neuropathy	52	35 (67.3)	6.49; 0.011
No peripheral neuropathy	109	50 (45.9)	
On metformin	137	75 (54.7)	1.40; 0.236
Not on metformin	24	10 (41.7)	
On an SGLT2 inhibitor	46	25 (54.3)	0.06; 0.803
Not on an SGLT2 inhibitor	115	60 (52.2)	
On insulin	38	25 (65.8)	3.37; 0.066
Not on insulin	123	60 (48.8)	

Pearson's chi-square test without continuity correction, one degree of freedom; every expected cell count was at least 5.

7.9 Calf circumference against low strength or performance

7.9.1 Discrimination

Calf circumference is an AWGS 2019 case-finding measure and a surrogate of muscle mass. Against the presence of low handgrip strength or low physical performance, the reference for this analysis (109 participants with, 52 without), a smaller calf circumference gave an area under the ROC curve of 0.69 (95% CI 0.60–0.78, DeLong's method) (Figure 3). By sex, in a post hoc analysis that the protocol had not prespecified, the area was 0.76 (95% CI 0.65–0.86) in men, 55 with and 36 without low strength or performance, and 0.55 (0.38–0.72) in women, among whom only 16 were without it.

7.9.2 How to read the area

The pooled interval excluded 0.5, the value expected by chance, so a smaller calf went with weaker or slower muscle more often than chance would give, but the discrimination was modest; in women the interval included 0.5, so discrimination beyond chance was not shown. Calf circumference and the reference measure different properties of muscle, so the area describes the extent to which the two are

associated in this sample. It is not an estimate of the diagnostic accuracy of calf circumference.

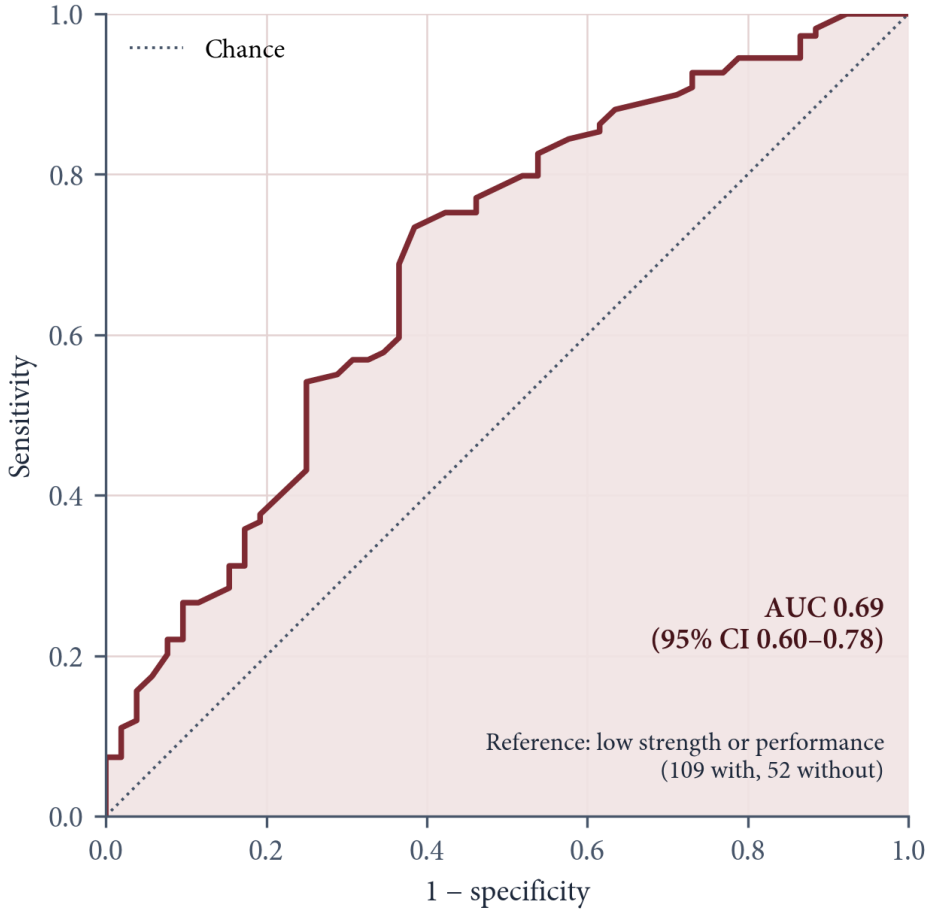

Figure 3 — ROC curve of calf circumference, a lower value counted as positive, against low handgrip strength or low physical performance, in all analysed participants. The dotted diagonal is the line of no discrimination.

8 Discussion

8.1 Principal findings

This hospital-based cross-sectional study applied the AWGS 2019 primary-care algorithm, with its case-finding step, to 161 adults aged 60 to 75 years with type 2 diabetes attending the General Medicine outpatient department of a tertiary-care teaching hospital in Karnataka. It has four principal findings.

- **Possible sarcopenia was common.** It was present in 52.8% of participants (95% CI 45.1–60.4), in similar proportions of men and women, and in 67.7% when the case-finding step was dropped.
- **It was associated with poorer glycaemic control.** The prevalence rose from 26.7% among participants with an HbA1c below 7% to 67.3% among those at 9% or more, and after adjustment for age, sex, BMI, duration of diabetes, physical activity and hypertension, an HbA1c of 9% or more carried a prevalence ratio of 1.41 (95% CI 1.09–1.82). The estimate was stable when possible mediators were added in an exploratory model.
- **Handgrip strength was lower with higher HbA1c.** The inverse correlation was weak ($\rho = -0.22$) but present in both sexes, and within each sex mean handgrip strength was lower at an HbA1c of 9% or more.
- **Calf circumference discriminated only modestly.** Against low strength or low performance, the area under its ROC curve was 0.69 (95% CI 0.60–0.78).

Each finding is an association measured at one visit. None is a diagnosis of sarcopenia, which would need a measurement of muscle mass, and none shows whether poor glycaemic control came before low muscle strength or after it.

8.2 Prevalence in context

8.2.1 Against sarcopenia defined with muscle mass

The prevalence of possible sarcopenia found here, 52.8% (95% CI 45.1–60.4), lies well above the pooled prevalence of sarcopenia defined with measured muscle mass. In the meta-analysis of Raj and colleagues, which brought together seven cross-sectional Indian studies (1,359 participants), sarcopenia by AWGS 2019 was 27.4% (Hartung–Knapp 95% CI 18.9–37.9%; six studies, 1,109 participants; I^2 = 91.7%).[10] Among Asian adults with type 2 diabetes, Yogesh and colleagues pooled 23% (95% CI 18–27%) from 39 studies that applied AWGS 2019,[11] and Wu and colleagues 17% (14–21%) from 43 studies of adults aged 45 years and over.[12] Even the lower limit of the present interval lies above all three; that is expected rather than contradictory. Possible sarcopenia requires only low muscle strength or low physical performance, so it identifies a wider group than sarcopenia, which also requires low muscle mass, and it is meant to: the category was defined for primary health care and community-based health promotion, where muscle mass is not measured.[1]

8.2.2 Against other estimates of possible sarcopenia

Published estimates of possible sarcopenia itself are higher but too heterogeneous to serve as a benchmark. Yogesh and colleagues pooled 61% (95% CI 28–86%) from five Asian studies, with I^2 = 98.8% and a prediction interval of 5% to 98%.[11] Raj and colleagues pooled 65.6% from three Indian studies (693 participants), with I^2 = 98.6% and a 95% prediction interval of 0.1% to 100%, and described the figure as a summary of three discordant estimates rather than an interpretable prevalence.[10] The present estimate lies inside both prediction intervals, which shows chiefly how much possible sarcopenia depends on how the pathway is applied; it does not show that the estimates agree. The hospital-based study of 404 adults from Gujarat, which defined possible sarcopenia by handgrip strength alone, reported 89.6%.[6] The prespecified

sensitivity estimate shows the same effect within one sample: dropping the case-finding step raised the proportion from 52.8% to 67.7%, a difference of 14.9 percentage points.

8.2.3 Which figure to quote

The two figures answer different readings of the pathway. Won, summarising the AWGS 2019 primary-care track, notes that clinical conditions, diabetes mellitus among them, can take the place of case-finding.[2] Compared with the 2019 version, the 2025 update added clinical conditions to the assessment recommended in the community setting.[13] On either reading a person with diabetes may go straight to strength and performance, and the sensitivity estimate is then the relevant figure. The study's protocol applied tool-based case-finding to everyone so that its outcome followed the published primary-care algorithm step by step; both figures are therefore reported, and a comparison should first match the method.

8.2.4 Where the Indian evidence comes from

None of the seven Indian studies pooled by Raj and colleagues came from South India, and six were based in tertiary care.[10] A South Indian estimate is therefore useful, but the present one also comes from a single tertiary centre and is not the prevalence in the community or in primary care.

8.3 Glycaemic control and possible sarcopenia

8.3.1 The association in context

Possible sarcopenia was more common with each step up in HbA1c, and the confidence interval of the adjusted prevalence ratio for an HbA1c of 9% or more lay wholly above 1. The direction agrees with the pooled Asian evidence on sarcopenia. Wu and colleagues found elevated HbA1c associated with sarcopenia (odds ratio 1.11, 95% CI 1.06–1.17; I^2 = 0%; moderate certainty of evidence).[12] Yogesh and colleagues found an odds ratio of 1.31 (95% CI 1.01–2.17) for HbA1c, from only

three studies (I^2 = 75.3%).[11] In India the evidence is thinner: in the meta-analysis by Raj and colleagues, uncontrolled HbA1c (8% or more) was associated with sarcopenia in a single study only (adjusted odds ratio 2.8, 95% CI 1.2–6.1), a camp-based study of 250 older adults in Gujarat that applied the AWGS 2014 criteria with BIA, and the finding has not been replicated[10]; and in the Odisha study of Sravya and colleagues, HbA1c and the other glycaemic measures showed no significant association at all.[5] These odds ratios describe sarcopenia defined with muscle mass (in India, by older criteria and an 8% threshold), so they are not directly comparable with the present estimates, and they should be set beside this study's adjusted odds ratio, 2.78, rather than its prevalence ratio, 1.41: with an outcome present in about half of the sample, the odds ratio overstates the prevalence ratio, which is why the prevalence ratio was prespecified as the primary measure.[7]

8.3.2 Why the Odisha study may differ

The Odisha study, of 159 adults with type 2 diabetes and 79 without, defined sarcopenia with muscle mass measured by DXA and found it in 22.5% and 8.86% respectively[5]; possible sarcopenia, by contrast, rests entirely on strength and performance. In the Baltimore Longitudinal Study of Aging, a largely non-diabetic community cohort of 984 participants aged 25 to 96 years whose HbA1c quartiles ran from below 5.5% to 6.1% or more, muscle strength and muscle quality were lower across quartiles of HbA1c while muscle mass was similar.[3] If glycaemia bears more on how well muscle works than on how much of it there is, an outcome built on strength would show an association that one built on mass could miss; without muscle mass, the present study can only note that its result fits that explanation.

8.3.3 Mediators and confounders

Peripheral neuropathy was more common among participants with possible sarcopenia, in keeping with Wu and colleagues and with the Odisha study,[5,12] and Kalyani and colleagues suggested that neuropathy may mediate part of the link between hyperglycaemia and lower strength.[3] When neuropathy and the three glucose-lowering drugs were added in model 2, the prevalence ratio was stable; with only 6.9 events per variable (computed from the 76 participants without possible sarcopenia), that is a reassurance about model 1, not evidence about mediation either way. Lower BMI went with possible sarcopenia, as higher BMI went with lower odds of sarcopenia in the pooled Asian analysis and low BMI with sarcopenia in Odisha[5,12]; possible sarcopenia was about as common in SGLT2-inhibitor users as in non-users, and a network meta-analysis of 33 trials (5,399 adults) found modest lean-mass reductions with some agents, with few trials reporting strength or performance.[14]

8.4 Handgrip strength, calf circumference and the case-finding step

8.4.1 Handgrip strength and HbA1c

The inverse correlation between handgrip strength and HbA1c was weak ($\rho = -0.22$), and of a size close to the coefficient of −0.24 ($p < 0.01$) that Laksmi and colleagues reported in 133 outpatients with type 2 diabetes in Jakarta, aged 40 to 59 years.[4] The two samples differ in age and setting, so the closeness of the two coefficients is a comparison, not a confirmation. That the correlation held within each sex matters, because handgrip strength differs greatly between men and women and a pooled correlation alone could reflect the mix of sexes. The mean differences in handgrip strength between participants with an HbA1c of 9% or more and those below 9%, −3.6 kg in men and −2.1 kg in women, are modest for an individual patient, but in both sexes the two groups' means lie close to the AWGS 2019 cut-off, where a few kilograms decide whether a patient is classified as having low strength.

8.4.2 Calf circumference as the case-finding tool

Calf circumference is one of the AWGS 2019 case-finding measures,[1,2] and a surrogate of muscle mass rather than of muscle function. Its discrimination of low strength or low performance was modest, with an area under the curve of 0.69. This is the expected consequence of asking a measure of size to identify a deficit of function, and it is why the area should not be read as diagnostic accuracy. It does have a practical meaning: case-finding by calf circumference or the SARC-F passes over some patients whose strength or performance is low, which is what the gap between the primary and the sensitivity estimates shows. In a post hoc analysis by sex, which the protocol had not prespecified, calf circumference did not discriminate beyond chance among women, few of whom were without low strength or performance (Results).

8.5 AWGS 2025 and this study

8.5.1 Why the study used AWGS 2019

The Asian Working Group for Sarcopenia published its 2025 consensus update[15] after this study's synopsis had been approved. Because the synopsis predates AWGS 2025, the study kept the AWGS 2019 criteria on which its protocol, its sample size and its case proforma were built; adopting the new criteria would have meant departing from the protocol the Institutional Ethics Committee approved. The choice also keeps the results comparable with the Indian evidence, since six of the seven Indian studies pooled by Raj and colleagues used AWGS 2019.[10]

8.5.2 What AWGS 2025 changes

The 2025 update moves the focus from sarcopenia to muscle health, extends assessment to middle-aged adults, and simplifies the diagnosis of sarcopenia to the combination of low muscle mass and low muscle strength, with physical performance becoming an outcome measure rather than a diagnostic criterion.[15] It keeps the 2019

handgrip cut-offs for adults aged 65 years and over; for adults aged 50 to 64 years it sets handgrip cut-offs of below 34 kg in men and below 20 kg in women, and a chair-stand threshold of 10 s or more for physical performance as an outcome measure; it retains possible sarcopenia for settings with limited resources; and it adds clinical conditions such as diabetes to the assessment in community settings.[13]

8.5.3 What that would mean for these participants

Three consequences follow. Participants aged 60 to 64 years would be judged against handgrip cut-offs of 34 kg and 20 kg rather than 28 kg and 18 kg.[13] Their chair-stand times would be read against 10 s rather than 12 s, but as a measure of outcome, not as a diagnostic criterion; whether low physical performance alone still identifies possible sarcopenia under AWGS 2025 is not stated in the published interpretation of the update,[13] so the participants classified here by their performance alone cannot be reclassified with confidence. And with diabetes itself prompting assessment in the community, the case-finding step would matter less. These changes pull in different directions, so the net effect on the prevalence cannot be stated without reclassifying each participant. Because handgrip strength, the chair stand, calf circumference and the SARC-F were all recorded as raw values in every participant, such a reclassification is possible in a secondary analysis, for every criterion except muscle mass.

8.6 Strengths

- **A prespecified protocol.** The outcome, the exposure, the sample size, the primary and the exploratory models, and the sensitivity estimate were all fixed in the synopsis before data collection.
- **Every measurement in every participant.** Calf circumference, the SARC-F, handgrip strength and the chair stand were taken in all participants, whatever

the case-finding result, so the sensitivity estimate and the ROC analysis are free of the bias that arises when only screen-positive participants are measured.

- **Standardised bedside methods.** Handgrip strength, the chair stand and calf circumference were measured by written protocols that agree with the standardised protocols an expert Delphi consensus later proposed,[16] and the AWGS 2019 cut-offs were applied at analysis by one written rule.
- **An effect measure suited to a common outcome.** The association was estimated as a prevalence ratio by modified Poisson regression, with the odds ratio alongside for comparison.[7]
- **Complete data.** Participants were enrolled consecutively, and only 7 of 168 proformas were incomplete.
- **A checked exposure.** HbA1c came from the hospital laboratory, with haemoglobin from the same sample so that anaemia could be recognised.

8.7 Limitations

- **The construct, not muscle mass[1].** Possible sarcopenia is a construct AWGS 2019 scopes for primary health care and community settings; here it was used in a tertiary-care outpatient department without measuring muscle mass, so the result is a bedside estimate and never a confirmed diagnosis.
- **The case-finding step[2].** Tool-based case-finding was applied to everyone, although diabetes may itself replace case-finding; the sensitivity estimate shows how much this step changed the result.
- **No temporality.** The design was cross-sectional: exposure and outcome were measured at the same visit, so the study showed associations and could not establish which came first.

- **Generalisability.** Participants were consecutive tertiary-care outpatients at a single centre, studied cross-sectionally: the findings are associations only and may not apply to primary care or the community.
- **Precision**[9]**.** The absolute precision of 8 percentage points was wider than the conventional 5%, and the association analyses were exploratory because the sample size covered the prevalence only.
- **The criteria**[13,15]**.** Under the AWGS 2025 update, participants aged 60 to 64 would be judged by middle-aged thresholds, and physical performance, including the chair stand, became an outcome measure rather than a diagnostic criterion; the estimate is specific to AWGS 2019.
- **A single HbA1c**[17]**.** Glycaemic control rested on a single HbA1c, which mild or moderate anaemia, including iron deficiency anaemia, can distort.
- **Physical activity**[8]**.** Physical activity was self-reported on the IPAQ-SF, whose agreement with objective measures is weak, so adjustment for it was imperfect.
- **Fitted probabilities above 1.** Modified Poisson regression does not keep its fitted probabilities below 1, and in model 1 a small number of participants had fitted probabilities above 1. The prevalence ratio by marginal standardisation from the logistic model agreed with the modified Poisson estimate (Results), so the primary estimate did not depend on this property of the model.
- **The exploratory model.** Model 2 had 6.9 events per variable (computed from the 76 participants without possible sarcopenia), below the conventional 10, so its stability could not separate mediation from confounding.
- **Calf circumference among women.** In a post hoc analysis by sex, not prespecified, calf circumference did not discriminate beyond chance among women (Results), and the comparison group of women without low strength or

performance was small, so the pooled area under the curve may not apply to women.

8.8 Implications

8.8.1 For practice

The AWGS 2019 primary-care pathway can be completed in a medical outpatient department with a tape, a questionnaire, a dynamometer and a chair, and in this sample it was positive in about half of older adults with type 2 diabetes. Possible sarcopenia was more common where glycaemic control was poor, so patients with an HbA1c of 9% or more are a reasonable group in whom to measure handgrip strength and the chair stand, and to offer the lifestyle advice that the pathway recommends for a positive result.[2] This is an argument for looking, not a claim that improving glycaemic control would restore strength; the design cannot show that.

8.8.2 For research

- A longitudinal study, to establish whether poor glycaemic control precedes the loss of strength, or follows it.
- A measurement of muscle mass in the same participants, so that possible sarcopenia can be set beside sarcopenia proper.
- A reanalysis, or a new study, under the AWGS 2025 criteria, including middle-aged adults.
- A multicentre South Indian sample that includes primary care, and an objective measure of physical activity in place of the IPAQ-SF.

9 Conclusion

In this sample of older adults with type 2 diabetes attending a tertiary-care outpatient department, possible sarcopenia by the AWGS 2019 primary-care criteria was common, and it was associated with poorer glycaemic control: its prevalence rose across HbA1c categories, and an HbA1c of 9% or more carried an adjusted prevalence ratio of 1.41. Handgrip strength was lower at higher HbA1c in both sexes. These are associations from a single, cross-sectional, bedside assessment without muscle mass; they identify a group worth assessing, and a question that only a longitudinal study can answer.

10 Summary

Possible sarcopenia, the category of the Asian Working Group for Sarcopenia (AWGS) 2019 consensus that is defined by low muscle strength or low physical performance alone, can be identified at the bedside with a tape, a questionnaire, a handgrip dynamometer and a chair. This study set out to estimate how often it is present in older adults with type 2 diabetes mellitus attending a General Medicine outpatient department, and whether it is associated with glycaemic control.

A hospital-based cross-sectional study enrolled 168 consecutive eligible adults aged 60 to 75 years with type 2 diabetes, of whom 161 with a complete proforma were analysed. Every participant had calf circumference, the SARC-F, handgrip strength and the five-times chair stand measured at one visit, and the AWGS 2019 primary-care algorithm was applied at analysis.

- Possible sarcopenia was present in 52.8% of participants (95% CI 45.1–60.4); without the case-finding step, 67.7% had low strength or low performance.
- The prevalence rose across HbA1c categories, from 26.7% below 7% to 67.3% at 9% or more (test for trend $p < 0.001$).
- After adjustment for age, sex, body mass index, duration of diabetes, physical activity and hypertension, an HbA1c of 9% or more carried a prevalence ratio of 1.41 (95% CI 1.09–1.82).
- Handgrip strength correlated inversely with HbA1c ($\rho = -0.22$), and calf circumference discriminated participants with low strength or performance only modestly (AUC 0.69).

Possible sarcopenia was common in this sample and was associated with poorer glycaemic control. Because muscle mass was not measured, none of these results is a

diagnosis of sarcopenia, and because the design is cross-sectional, none shows which came first.

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12 Annexures

12.1 Format of Consent Form (English)

Study title: Possible sarcopenia and its association with glycaemic control in older adults with type 2 diabetes mellitus: a hospital-based cross-sectional study

Sample form. This form belongs to an invented study made to show the RGUHS thesis format. No participant signed it.

12.1.1 Participant information sheet

You are invited to take part in a study of muscle strength in adults aged 60 to 75 years who have type 2 diabetes. Before you decide, please read this sheet, or have it read to you, and ask any question you have.

Why is the study being done? In older adults with diabetes, muscles can become weaker. Simple bedside tests can show this early, and the study asks how often it happens and whether it is linked with blood sugar control.

What will happen if I take part? At one visit, the investigator will measure your calf with a tape, ask you five short questions about strength and falls, measure your grip with a hand dynamometer, and time you standing up from a chair five times. Your HbA1c and haemoglobin will be read from the blood sample already taken for your routine diabetes care. No extra blood is taken and no medicine is given.

Are there any risks? The tests are those used in routine clinics. You may feel tired for a short while after the grip and chair tests. You may stop any test at any time.

Will I benefit? If the tests show weak muscles, you and your doctor will be told, so that advice on activity and diet can be given.

Is my information kept private? You will be identified only by a serial number. Your name will not appear in any report.

Do I have to take part? No. Taking part is voluntary, and you may withdraw at any time without giving a reason. Your treatment will not be affected in any way.

12.1.2 Informed consent

Participant serial number	

I confirm that I have read, or have had read to me, the information sheet for this study, and that I have had the opportunity to ask questions.

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without my medical care being affected.

I agree that the information collected may be used for scientific purposes, without my name being disclosed.

I agree to take part in this study.

Signature or thumb impression of the participant	
Date	
Name and signature of the investigator	
Date	
Name and signature of the impartial witness	
Date	

12.2 Format of Consent Form (Kannada)

The Kannada translation of this form, as approved by the Institutional Ethics Committee, is placed here. It is not reproduced in this sample.

12.3 Ethical Committee Clearance Letter

[The Institutional Ethics Committee clearance certificate issued by the IEC of Sample Medical College, Bengaluru is enclosed here.]

12.4 Case Proforma for the Study

The following standardised proforma was used to record the data of every participant enrolled in the study.

Identification	
Participant serial number	
Date of assessment	
Written informed consent obtained	[ ] Yes [ ] No
Assessed by (signature)	
Eligibility	
Inclusion	Aged 60 to 75 years. [ ] Yes [ ] No
Inclusion	Type 2 diabetes mellitus diagnosed at least one year before enrolment. [ ] Yes [ ] No
Inclusion	Able to stand up and walk without help. [ ] Yes [ ] No
Inclusion	Written informed consent. [ ] Yes [ ] No
Exclusion	Type 1 diabetes, or diabetes secondary to another disease. [ ] Yes [ ] No
Exclusion	A condition that prevents valid handgrip or chair-stand testing: surgery or injury of the hand, wrist, hip or knee in the past six months; joint pain, or a flare of arthritis in the hands, hips or knees, that prevents maximal effort on either test; stroke with residual weakness; Parkinson's disease; or a lower-limb amputation. [ ] Yes [ ] No
Exclusion	Bilateral pitting oedema of the legs, for example from heart failure, advanced chronic kidney disease or chronic liver disease. [ ] Yes [ ] No
Exclusion	A condition in which HbA1c may not reflect glycaemia: severe anaemia (judged clinically; no haemoglobin threshold is set), a known haemoglobinopathy (such as sickle cell disease or thalassaemia) or G6PD deficiency, or a blood transfusion in the past three months. [ ] Yes [ ] No
Exclusion	Acute illness, or admission to hospital, in the past four weeks. [ ] Yes [ ] No

Exclusion	Cognitive impairment or psychiatric illness that prevents consent or completing the SARC-F. [ ] Yes [ ] No
Exclusion	Current systemic glucocorticoid therapy, or a malignancy under active treatment. [ ] Yes [ ] No
Clinical details	
Age (years)	
Sex	[ ] Male [ ] Female
Duration of diabetes (years since diagnosis)	
Known hypertension	[ ] Yes [ ] No
Peripheral neuropathy (case file or 10-g monofilament)	[ ] Yes [ ] No
Current metformin	[ ] Yes [ ] No
Current SGLT2 inhibitor	[ ] Yes [ ] No
Current insulin	[ ] Yes [ ] No
Other glucose-lowering drugs	
Weight (kg)	
Height (cm)	
BMI (kg/m²)	
HbA1c (%), from the enrolment visit	
Haemoglobin (g/dL), same sample	
Physical activity (IPAQ-SF)	

Activity in the past week	**Days**	**Minutes per day**
Vigorous activity		
Moderate activity		
Walking		

Total physical activity (MET-min/week)	
SARC-F	
Strength (0, 1 or 2)	
Assistance in walking (0, 1 or 2)	
Rising from a chair (0, 1 or 2)	
Climbing stairs (0, 1 or 2)	

Falls (0, 1 or 2)	
SARC-F total (out of 10)	
Calf circumference	
Right calf (cm)	
Left calf (cm)	
Larger value (cm)	
Below the cut-off (34 cm in men, 33 cm in women)	[ ] Yes [ ] No
Handgrip strength	

Hand	**First trial (kg)**	**Second trial (kg)**
Right		
Left		

Maximum of all trials (kg)	
Low handgrip strength (below 28 kg in men, 18 kg in women)	[ ] Yes [ ] No
Five-times chair stand	
First trial (s)	
Second trial (s)	
Fastest time (s)	
Completed five rises without using the arms	[ ] Yes [ ] No
Low physical performance (12 s or more, or unable)	[ ] Yes [ ] No
Classification, completed at analysis	
Case-found (low calf circumference or a SARC-F score of 4 or more)	[ ] Yes [ ] No
Low strength or low performance	[ ] Yes [ ] No
Possible sarcopenia (AWGS 2019 primary-care algorithm)	[ ] Yes [ ] No

12.5 Masterchart

The complete de-identified master chart is presented below, organised by data-collection section. Identifying details (name, hospital number) have been removed; each participant is identified by case number only.

Every row is an invented participant; no patient took part in this sample study.

analysed: whether the proforma was complete (incomplete proformas were excluded, as planned); missing_item: the item that was missing.

duration_band and hba1c_band: the analysis categories; case_found, low_strength_or_performance and possible_sarcopenia: the AWGS 2019 primary-care steps, applied at analysis.

Master chart

Case	analysed	missing_ item	age	sex	bmi	duration_ yr	duration_ band	hba1c	hba1c_ band	haemoglobin	physical_ activity	peripheral_ neuropathy	on_ metformin	on_sglt2_ inhibitor	on_ insulin	hypertension	calf_ cm	sarc_ f	grip_ kg	chair_ stand_ s
1	yes		70	male	25.0	11	≥10	7.0	7–8.9	15.5	528	no	yes	no	no	no	33.2	1	30	11.4
2	yes		64	female	25.4	8	<10	7.3	7–8.9	11.4	1468	no	yes	no	no	yes	30.7	1	18	11.0
3	yes		62	female	28.1	10	≥10	8.8	7–8.9	12.1	792	no	yes	no	no	yes	33.6	0	20	13.2
4	yes		62	male	28.0	7	<10	7.7	7–8.9	12.7	576	no	yes	no	no	no	37.7	0	45	8.1
5	yes		63	female	26.4	1	<10	8.1	7–8.9	12.3	396	yes	yes	no	no	yes	32.8	5	16	16.6
6	yes		61	male	22.1	3	<10	8.2	7–8.9	13.0	594	no	no	no	no	no	30.9	1	26	10.3
7	yes		73	male	25.0	3	<10	6.0	<7	15.1	0	no	yes	no	no	no	32.4	4	22	15.4
8	yes		66	female	27.1	18	≥10	7.5	7–8.9	11.0	914	yes	no	no	no	no	34.8	2	23	13.2
9	yes		71	female	26.3	22	≥10	6.6	<7	12.4	297	yes	yes	no	no	yes	35.0	2	16	18.5
10	yes		74	male	29.3	14	≥10	7.6	7–8.9	14.0	132	yes	no	yes	yes	no	35.4	7	22	14.0
11	yes		60	female	24.1	15	≥10	9.1	≥9	11.1	1866	no	yes	no	no	yes	30.0	0	15	11.2
12	no	SARC-F	62	male	28.7	9	<10	7.2	7–8.9	14.8	396	no	yes	no	yes	no	34.8		35	11.1
13	yes		60	female	33.7	7	<10	8.1	7–8.9	12.5	693	no	yes	no	no	yes	36.1	0	23	8.3
14	yes		65	female	31.8	10	≥10	7.0	7–8.9	12.5	0	yes	yes	no	no	no	34.5	0	16	13.2
15	yes		65	female	32.4	6	<10	8.9	7–8.9	11.8	876	no	yes	yes	no	yes	35.1	5	20	10.3
16	yes		74	female	20.9	5	<10	6.1	<7	11.5	891	no	yes	no	no	yes	29.1	0	19	9.7
17	yes		72	female	24.3	13	≥10	9.2	≥9	9.8	198	yes	yes	no	yes	yes	31.9	7	10	13.7
18	yes		63	male	25.7	28	≥10	8.7	7–8.9	13.3	1380	no	yes	yes	yes	yes	34.9	0	37	10.2
19	yes		62	male	21.3	7	<10	7.7	7–8.9	13.3	555	no	yes	no	no	no	26.1	0	24	13.8
20	yes		70	female	22.4	22	≥10	7.7	7–8.9	15.1	297	no	yes	no	yes	no	29.8	3	13	15.0
21	yes		66	male	27.7	25	≥10	12.3	≥9	14.4	198	yes	yes	no	yes	yes	35.1	4	25	16.7
22	no	IPAQ-SF	60	female	22.5	10	≥10	10.0	≥9	9.4		no	yes	no	yes	no	28.4	0	14	11.1
23	yes		67	female	19.5	15	≥10	13.0	≥9	10.3	66	yes	yes	yes	yes	yes	31.3	2	13	17.8
24	yes		75	male	21.3	2	<10	9.2	≥9	14.5	99	no	yes	no	no	yes	31.3	0	27	10.5
25	yes		67	female	22.0	11	≥10	7.8	7–8.9	11.4	1050	no	yes	no	no	yes	31.7	2	16	12.9
26	yes		67	female	24.2	7	<10	7.6	7–8.9	13.5	495	no	yes	no	no	yes	34.1	4	17	10.4
27	yes		62	male	21.8	9	<10	8.0	7–8.9	15.2	66	yes	yes	yes	no	no	31.3	8	22	18.8
28	no	HbA1c report	72	female	27.0	10	≥10				924	no	yes	no	no	no	31.6	0	20	8.8
29	yes		71	male	32.7	24	≥10	7.9	7–8.9	13.2	0	yes	yes	yes	yes	yes	37.1	6	22	18.7
30	yes		62	male	25.6	20	≥10	7.9	7–8.9	12.2	918	yes	yes	no	no	yes	33.7	5	29	11.5
31	yes		73	female	25.3	10	≥10	8.9	7–8.9	11.1	297	no	no	yes	no	no	30.8	6	8	16.2
32	yes		70	male	27.1	13	≥10	10.4	≥9	14.8	198	no	yes	no	yes	yes	34.5	4	22	10.4
33	yes		66	male	29.0	8	<10	6.6	<7	14.2	990	no	yes	no	no	yes	35.7	1	32	10.1
34	yes		75	male	21.4	19	≥10	7.2	7–8.9	12.5	297	no	yes	no	no	yes	29.4	0	30	12.1
35	yes		64	male	21.6	16	≥10	7.6	7–8.9	12.9	1279.5	no	yes	no	no	no	30.5	1	25	10.8
36	yes		67	female	22.7	12	≥10	7.2	7–8.9	12.9	495	no	yes	no	no	yes	26.8	4	12	17.5
37	yes		69	male	23.7	15	≥10	9.3	≥9	13.2	99	yes	yes	yes	yes	yes	32.7	5	24	16.2
38	yes		66	male	27.6	33	≥10	13.4	≥9	12.0	396	yes	yes	yes	yes	yes	32.1	8	17	17.1

Case	analysed	missing_ item	age	sex	bmi	duration_ yr	duration_ band	hba1c	hba1c_ band	haemoglobin	physical_ activity	peripheral_ neuropathy	on_ metformin	on_sglt2_ inhibitor	on_ insulin	hypertension	calf_ cm	sarc_ f	grip_ kg	chair_ stand_ s
39	yes		73	male	26.5	7	<10	6.2	<7	15.7	516	no	yes	no	no	yes	37.0	0	31	14.0
40	yes		68	male	22.9	7	<10	7.3	7–8.9	12.1	529.5	no	yes	no	no	yes	32.3	3	25	17.4
41	yes		65	male	23.3	10	≥10	6.8	<7	15.7	198	no	yes	yes	no	yes	33.8	0	29	11.4
42	yes		60	male	25.3	6	<10	10.3	≥9	14.4	99	no	yes	no	no	yes	33.4	2	25	13.0
43	yes		68	male	25.4	7	<10	7.7	7–8.9	11.8	396	no	no	yes	no	no	34.5	0	38	9.1
44	yes		69	female	29.0	5	<10	8.6	7–8.9	13.6	120	yes	yes	no	no	yes	33.6	7	17	23.0
45	yes		69	male	25.9	14	≥10	8.4	7–8.9	14.5	396	yes	yes	no	no	no	35.1	8	28	18.3
46	yes		64	male	22.5	8	<10	11.2	≥9	13.0	675	yes	yes	no	yes	no	33.6	2	24	10.5
47	yes		67	male	29.3	18	≥10	12.2	≥9	12.2	495	no	yes	no	yes	yes	34.4	1	21	14.0
48	yes		63	female	28.4	7	<10	9.2	≥9	10.7	834	no	yes	no	no	no	35.3	0	18	10.4
49	yes		64	female	26.0	23	≥10	8.9	7–8.9	13.0	1140	yes	no	no	no	no	35.3	5	17	12.5
50	yes		62	male	28.3	9	<10	7.6	7–8.9	12.9	396	yes	yes	no	no	no	35.9	2	31	14.0
51	yes		74	female	24.4	9	<10	6.4	<7	13.6	0	no	yes	yes	no	yes	32.8	1	19	9.0
52	yes		64	male	26.3	10	≥10	6.5	<7	14.1	396	no	yes	no	no	no	33.5	0	26	16.2
53	yes		75	male	27.2	9	<10	6.2	<7	12.7	477	no	yes	no	no	yes	35.4	0	35	11.9
54	yes		61	female	23.4	5	<10	8.3	7–8.9	14.2	1626	no	yes	no	no	yes	31.6	3	16	10.0
55	yes		62	male	21.2	9	<10	7.1	7–8.9	14.6	657	no	yes	yes	no	yes	30.5	6	32	9.2
56	yes		63	male	19.5	10	≥10	9.4	≥9	15.2	1446	no	yes	no	yes	yes	31.1	5	30	10.4
57	yes		66	male	27.4	4	<10	8.0	7–8.9	13.8	132	no	no	no	yes	yes	34.7	1	26	11.6
58	yes		62	male	28.2	18	≥10	11.3	≥9	12.4	693	no	yes	yes	yes	no	36.5	0	31	9.3
59	yes		64	male	25.2	15	≥10	12.5	≥9	12.2	579	no	yes	no	yes	yes	34.5	5	32	9.8
60	yes		64	male	26.2	7	<10	8.4	7–8.9	15.0	198	no	no	yes	no	yes	38.7	0	43	8.6
61	yes		69	female	24.2	5	<10	10.4	≥9	11.5	1296	no	yes	no	no	no	30.6	3	15	11.4
62	yes		61	female	22.7	2	<10	6.4	<7	12.4	438	no	yes	no	no	yes	32.1	1	25	10.6
63	yes		62	female	28.4	5	<10	8.0	7–8.9	12.3	735	no	yes	no	no	no	33.2	1	16	10.5
64	yes		63	female	28.5	5	<10	7.2	7–8.9	13.2	417	no	yes	no	no	yes	37.7	2	20	14.7
65	yes		65	male	25.7	5	<10	8.0	7–8.9	13.0	33	no	yes	yes	no	yes	34.7	1	27	9.4
66	yes		70	male	22.6	8	<10	7.7	7–8.9	13.9	1279.5	no	yes	no	no	no	30.2	0	23	13.5
67	yes		62	male	31.2	10	≥10	9.2	≥9	12.7	1268	no	no	no	no	no	35.2	0	33	10.5
68	yes		67	male	29.6	12	≥10	8.7	7–8.9	14.0	1575	yes	yes	no	no	yes	33.5	1	21	14.0
69	yes		60	female	27.6	6	<10	10.1	≥9	11.1	1104	no	yes	yes	no	no	31.7	1	15	11.8
70	yes		66	female	32.7	3	<10	9.2	≥9	11.5	396	no	yes	yes	no	yes	37.6	0	22	12.6
71	yes		64	female	25.5	12	≥10	7.2	7–8.9	15.0	297	no	yes	yes	no	no	35.3	3	26	10.3
72	yes		72	female	27.4	12	≥10	10.5	≥9	11.4	66	yes	yes	no	no	yes	33.4	7	14	20.2
73	yes		66	female	22.6	5	<10	6.1	<7	11.0	714	no	yes	no	no	yes	30.3	0	17	7.4
74	yes		71	male	26.8	11	≥10	9.7	≥9	14.6	498	no	yes	yes	yes	no	37.4	5	30	14.6
75	yes		64	male	32.3	3	<10	8.0	7–8.9	14.7	792	no	no	no	no	no	41.0	0	37	8.6
76	yes		72	male	25.1	20	≥10	10.1	≥9	13.6	297	no	yes	yes	yes	yes	33.4	3	25	17.2
77	yes		67	male	28.0	7	<10	7.3	7–8.9	14.5	660	no	yes	yes	no	yes	35.9	0	37	10.6
78	yes		68	female	24.3	5	<10	11.9	≥9	13.4	396	yes	yes	no	no	yes	32.9	1	21	10.7
79	no	HbA1c report	72	female	23.7	3	<10				99	no	yes	yes	no	no	28.4	5	13	13.2
80	yes		63	female	27.7	9	<10	8.2	7–8.9	12.4	813	no	yes	yes	no	no	35.2	0	19	11.3
81	yes		70	male	22.0	2	<10	7.1	7–8.9	14.2	1199.5	no	yes	no	no	no	30.3	2	28	7.7
82	yes		66	male	23.8	10	≥10	7.7	7–8.9	14.3	792	no	yes	yes	no	yes	31.0	1	24	11.2
83	yes		65	male	23.2	32	≥10	10.7	≥9	14.1	1074	no	no	yes	yes	no	33.7	1	24	11.0
84	yes		70	female	24.0	14	≥10	7.9	7–8.9	11.6	396	no	yes	yes	yes	yes	30.3	2	13	15.3
85	yes		67	male	29.4	6	<10	8.9	7–8.9	14.2	33	no	yes	no	no	yes	38.9	0	38	9.2
86	no	SARC-F	68	male	30.2	12	≥10	6.5	<7	12.9	264	no	yes	no	no	yes	36.7		35	10.5
87	yes		65	female	25.2	6	<10	7.1	7–8.9	14.3	984	no	yes	no	no	no	32.3	1	18	13.2
88	yes		61	female	20.4	10	≥10	7.6	7–8.9	13.2	198	yes	yes	no	no	no	31.2	3	17	7.0
89	yes		69	male	27.1	4	<10	7.8	7–8.9	12.8	1494	yes	yes	no	no	yes	33.5	0	21	14.3
90	yes		62	male	30.7	9	<10	7.6	7–8.9	13.9	699	no	yes	no	no	yes	35.7	0	34	9.3
91	yes		71	female	31.8	10	≥10	7.0	7–8.9	9.6	132	no	yes	no	no	yes	34.9	5	20	12.6
92	yes		63	female	26.3	20	≥10	12.1	≥9	11.4	2239.5	no	yes	yes	yes	no	33.6	0	15	11.6
93	yes		63	male	23.1	5	<10	6.9	<7	13.4	297	yes	yes	no	no	yes	30.6	5	30	13.9
94	yes		66	male	25.8	15	≥10	7.5	7–8.9	13.1	1230	no	yes	no	no	yes	32.1	0	30	11.2
95	yes		61	female	31.8	15	≥10	7.2	7–8.9	12.1	660	no	yes	no	no	no	35.6	0	17	11.8
96	yes		65	male	26.5	8	<10	9.3	≥9	11.4	792	no	yes	no	no	yes	32.1	2	23	14.5

Case	analysed	missing_ item	age	sex	bmi	duration_ yr	duration_ band	hba1c	hba1c_ band	haemoglobin	physical_ activity	peripheral_ neuropathy	on_ metformin	on_sglt2_ inhibitor	on_ insulin	hypertension	calf_ cm	sarc_ f	grip_ kg	chair_ stand_ s
97	yes		64	male	28.5	12	≥10	7.7	7–8.9	14.8	528	no	yes	no	no	yes	37.3	0	32	7.8
98	yes		72	male	25.4	27	≥10	13.5	≥9	13.6	0	yes	yes	yes	yes	yes	31.8	0	28	12.5
99	yes		73	female	19.8	4	<10	5.8	<7	12.3	528	no	yes	no	no	no	28.2	9	9	20.4
100	yes		69	female	23.2	3	<10	7.5	7–8.9	11.1	198	yes	yes	no	no	no	32.2	0	19	12.6
101	yes		74	female	32.4	10	≥10	9.0	≥9	11.7	0	yes	yes	no	yes	yes	37.2	3	12	12.0
102	yes		64	female	30.7	13	≥10	9.4	≥9	9.6	0	yes	yes	yes	no	yes	32.9	0	17	12.9
103	yes		62	male	20.3	17	≥10	6.2	<7	14.5	1702.5	no	yes	no	no	no	31.2	4	28	10.4
104	yes		64	male	19.6	5	<10	8.6	7–8.9	15.8	792	no	no	yes	no	yes	32.0	4	26	9.7
105	yes		66	male	16.8	10	≥10	13.5	≥9	14.4	99	yes	yes	yes	yes	no	28.5	9	13	
106	yes		66	female	25.4	3	<10	11.0	≥9	11.8	660	no	yes	yes	no	yes	33.1	3	17	12.8
107	yes		68	male	29.0	3	<10	9.8	≥9	15.5	297	no	no	no	yes	no	36.4	0	30	10.9
108	yes		72	female	32.2	10	≥10	6.5	<7	12.8	742.5	yes	yes	no	yes	yes	35.9	1	25	13.4
109	yes		63	female	28.5	3	<10	6.3	<7	12.1	693	no	yes	no	no	yes	33.5	0	15	11.3
110	yes		62	male	20.5	12	≥10	6.3	<7	15.8	556	no	no	no	no	no	33.1	0	34	9.6
111	yes		69	male	21.8	5	<10	6.7	<7	14.1	0	yes	yes	no	no	no	33.8	7	29	7.9
112	yes		65	male	20.5	2	<10	8.8	7–8.9	10.7	132	no	yes	no	no	yes	32.3	6	30	12.6
113	yes		60	female	23.4	5	<10	7.9	7–8.9	10.6	264	no	yes	no	no	no	30.5	3	19	12.6
114	no	handgrip	69	male	23.4	22	≥10	9.1	≥9	13.6	798	no	yes	no	no	no	31.8	8		16.2
115	yes		66	male	28.6	6	<10	6.3	<7	12.5	1188	yes	yes	no	no	yes	37.6	0	29	10.1
116	yes		67	male	22.6	2	<10	7.1	7–8.9	13.8	660	yes	no	no	no	yes	30.9	2	24	10.6
117	yes		72	male	25.1	7	<10	7.8	7–8.9	13.2	922.5	yes	yes	no	no	yes	31.2	4	25	12.8
118	yes		69	male	18.4	10	≥10	7.6	7–8.9	13.1	132	no	yes	no	no	yes	32.5	1	19	9.3
119	yes		63	female	22.3	5	<10	11.9	≥9	11.5	900	no	yes	yes	no	yes	32.0	0	18	11.7
120	yes		70	female	26.6	10	≥10	6.6	<7	11.9	148.5	yes	yes	yes	no	yes	34.0	2	18	13.0
121	yes		67	male	27.6	6	<10	8.5	7–8.9	12.8	360	no	yes	no	no	yes	34.9	0	32	10.2
122	yes		69	female	24.4	18	≥10	9.0	≥9	11.1	198	no	yes	no	no	yes	32.3	5	17	8.7
123	yes		69	female	25.7	14	≥10	9.1	≥9	13.1	693	yes	no	no	no	no	33.2	4	17	13.2
124	yes		67	male	27.4	20	≥10	8.3	7–8.9	15.9	1020	yes	no	no	yes	yes	35.2	1	27	12.9
125	yes		69	female	21.8	20	≥10	6.7	<7	12.7	297	yes	yes	no	yes	yes	29.7	3	19	11.3
126	yes		71	male	22.8	27	≥10	9.4	≥9	13.2	396	yes	yes	no	yes	no	29.4	5	18	20.2
127	yes		67	male	21.9	5	<10	9.6	≥9	14.0	297	no	yes	no	no	yes	32.9	0	21	12.6
128	yes		63	female	20.3	14	≥10	13.0	≥9	12.7	933	yes	yes	yes	yes	no	32.4	1	14	15.1
129	yes		61	female	20.4	12	≥10	8.8	7–8.9	12.2	198	no	yes	no	no	no	28.3	0	16	10.1
130	yes		69	female	21.1	20	≥10	8.1	7–8.9	10.6	1039.5	no	yes	no	no	no	29.6	8	21	
131	yes		69	male	23.1	2	<10	9.6	≥9	11.3	297	no	yes	no	no	yes	33.6	1	32	12.8
132	yes		66	female	23.2	23	≥10	8.6	7–8.9	13.7	1926	no	yes	no	no	yes	31.2	0	20	11.8
133	yes		68	male	22.8	7	<10	6.6	<7	13.9	396	no	yes	no	no	yes	32.6	1	20	12.2
134	yes		75	female	20.5	14	≥10	11.4	≥9	10.7	1104	no	yes	no	no	no	28.0	2	15	11.3
135	yes		72	female	30.3	9	<10	8.5	7–8.9	13.4	66	no	yes	yes	no	yes	34.8	1	19	13.6
136	yes		61	male	25.0	23	≥10	6.6	<7	15.1	1364	yes	yes	yes	yes	yes	34.8	0	36	9.7
137	yes		62	male	26.2	12	≥10	6.5	<7	12.6	1236	yes	yes	no	no	yes	34.4	3	35	11.2
138	no	HbA1c report	68	male	25.6	20	≥10				0	no	yes	no	yes	yes	29.7	9	21	26.7
139	yes		71	male	23.6	18	≥10	8.9	7–8.9	12.4	297	yes	yes	yes	yes	yes	29.7	2	17	15.7
140	yes		70	male	18.6	27	≥10	8.8	7–8.9	13.2	396	yes	yes	no	yes	no	27.1	5	24	16.2
141	yes		70	male	25.1	5	<10	9.6	≥9	13.3	0	no	yes	yes	no	no	33.7	0	27	15.9
142	yes		71	female	23.3	20	≥10	10.6	≥9	9.1	99	no	no	no	yes	yes	32.6	1	14	11.3
143	yes		67	male	29.4	2	<10	6.3	<7	11.8	1032	no	yes	no	no	no	39.4	4	35	10.5
144	yes		68	male	25.4	1	<10	6.2	<7	11.4	99	no	no	no	no	no	34.8	0	35	10.6
145	yes		64	male	27.5	3	<10	7.0	7–8.9	13.2	1392	no	yes	no	no	yes	34.7	0	27	10.5
146	yes		73	male	16.8	5	<10	6.8	<7	12.4	132	no	yes	no	no	no	32.1	2	31	
147	yes		65	male	20.7	4	<10	8.6	7–8.9	16.9	1548	yes	yes	no	no	yes	29.6	2	24	17.3
148	yes		75	female	30.3	11	≥10	8.0	7–8.9	11.7	0	yes	yes	yes	no	yes	32.5	2	16	16.0
149	yes		67	male	23.1	7	<10	8.0	7–8.9	10.6	396	no	yes	yes	no	yes	33.6	0	34	8.0
150	yes		60	male	24.4	5	<10	7.9	7–8.9	12.4	396	no	yes	no	no	no	34.6	0	30	11.7
151	yes		61	female	29.4	10	≥10	10.1	≥9	10.8	198	no	no	no	no	yes	36.9	0	19	9.6
152	yes		71	female	30.6	12	≥10	6.8	<7	13.3	396	no	no	no	no	yes	33.3	2	19	
153	yes		62	female	25.9	3	<10	7.1	7–8.9	12.4	495	no	yes	no	no	no	31.8	0	22	8.9
154	yes		61	female	25.2	2	<10	9.9	≥9	13.8	99	no	yes	no	yes	yes	30.8	1	15	10.8

Case	analysed	missing_ item	age	sex	bmi	duration_ yr	duration_ band	hba1c	hba1c_ band	haemoglobin	physical_ activity	peripheral_ neuropathy	on_ metformin	on_sglt2_ inhibitor	on_ insulin	hypertension	calf_ cm	sarc_ f	grip_ kg	chair_ stand_ s
155	yes		74	female	26.7	9	<10	8.6	7–8.9	10.2	99	yes	yes	no	no	yes	33.4	6	18	12.2
156	yes		71	male	28.0	8	<10	7.4	7–8.9	12.5	891	no	yes	yes	no	no	33.4	4	26	15.0
157	yes		70	male	24.0	7	<10	7.8	7–8.9	13.8	264	no	yes	no	no	yes	30.2	6	22	13.8
158	yes		72	female	23.0	31	≥10	6.6	<7	13.5	33	yes	yes	yes	yes	yes	32.1	7	14	16.7
159	yes		68	male	23.2	10	≥10	7.7	7–8.9	14.3	99	no	no	no	no	yes	31.5	6	28	11.0
160	yes		69	male	27.9	16	≥10	9.4	≥9	13.3	897	yes	no	no	yes	yes	32.0	9	18	14.6
161	yes		61	male	21.3	13	≥10	11.4	≥9	12.1	2226	no	yes	yes	no	yes	31.6	0	25	8.6
162	yes		64	female	27.7	26	≥10	9.4	≥9	12.3	0	no	yes	no	yes	yes	31.6	6	12	14.1
163	yes		63	female	31.3	2	<10	7.2	7–8.9	12.2	66	no	yes	no	no	yes	30.5	4	21	15.4
164	yes		65	male	19.5	7	<10	8.3	7–8.9	12.2	396	yes	yes	yes	no	yes	28.4	7	23	18.6
165	yes		65	female	28.2	4	<10	9.6	≥9	15.0	297	yes	yes	no	no	no	35.6	0	21	12.4
166	yes		66	male	23.6	15	≥10	8.4	7–8.9	13.1	0	no	no	no	no	no	33.0	2	28	11.8
167	yes		62	male	22.4	25	≥10	9.0	≥9	15.9	954	yes	yes	yes	no	no	33.7	3	30	10.5
168	yes		61	female	29.5	11	≥10	6.8	<7	13.7	1566	no	yes	no	no	no	32.8	0	21	10.3

Master chart (cont.)

Case	chair_ stand_ completed	case_ found	low_ strength_ or_ performance	possible_ sarcopenia
1	yes	yes	no	no
2	yes	yes	no	no
3	yes	no	yes	no
4	yes	no	no	no
5	yes	yes	yes	yes
6	yes	yes	yes	yes
7	yes	yes	yes	yes
8	yes	no	yes	no
9	yes	no	yes	no
10	yes	yes	yes	yes
11	yes	yes	yes	yes
12	yes			
13	yes	no	no	no
14	yes	no	yes	no
15	yes	yes	no	no
16	yes	yes	no	no
17	yes	yes	yes	yes
18	yes	no	no	no
19	yes	yes	yes	yes
20	yes	yes	yes	yes
21	yes	yes	yes	yes
22	yes			
23	yes	yes	yes	yes
24	yes	yes	yes	yes
25	yes	yes	yes	yes
26	yes	yes	yes	yes
27	yes	yes	yes	yes
28	yes			
29	yes	yes	yes	yes
30	yes	yes	no	no
31	yes	yes	yes	yes
32	yes	yes	yes	yes
33	yes	no	no	no
34	yes	yes	yes	yes
35	yes	yes	yes	yes
36	yes	yes	yes	yes
37	yes	yes	yes	yes

Case	chair_ stand_ completed	case_ found	low_ strength_ or_ performance	possible_ sarcopenia
38	yes	yes	yes	yes
39	yes	no	yes	no
40	yes	yes	yes	yes
41	yes	yes	no	no
42	yes	yes	yes	yes
43	yes	no	no	no
44	yes	yes	yes	yes
45	yes	yes	yes	yes
46	yes	yes	yes	yes
47	yes	no	yes	no
48	yes	no	no	no
49	yes	yes	yes	yes
50	yes	no	yes	no
51	yes	yes	no	no
52	yes	yes	yes	yes
53	yes	no	no	no
54	yes	yes	yes	yes
55	yes	yes	no	no
56	yes	yes	no	no
57	yes	no	yes	no
58	yes	no	no	no
59	yes	yes	no	no
60	yes	no	no	no
61	yes	yes	yes	yes
62	yes	yes	no	no
63	yes	no	yes	no
64	yes	no	yes	no
65	yes	no	yes	no
66	yes	yes	yes	yes
67	yes	no	no	no
68	yes	yes	yes	yes
69	yes	yes	yes	yes
70	yes	no	yes	no
71	yes	no	no	no
72	yes	yes	yes	yes
73	yes	yes	yes	yes
74	yes	yes	yes	yes
75	yes	no	no	no
76	yes	yes	yes	yes
77	yes	no	no	no
78	yes	yes	no	no
79	yes			
80	yes	no	no	no
81	yes	yes	no	no
82	yes	yes	yes	yes
83	yes	yes	yes	yes
84	yes	yes	yes	yes
85	yes	no	no	no
86	yes			
87	yes	yes	yes	yes
88	yes	yes	yes	yes
89	yes	yes	yes	yes
90	yes	no	no	no
91	yes	yes	yes	yes
92	yes	no	yes	no
93	yes	yes	yes	yes
94	yes	yes	no	no

Case	chair_ stand_ completed	case_ found	low_ strength_ or_ performance	possible_ sarcopenia
95	yes	no	yes	no
96	yes	yes	yes	yes
97	yes	no	no	no
98	yes	yes	yes	yes
99	yes	yes	yes	yes
100	yes	yes	yes	yes
101	yes	no	yes	no
102	yes	yes	yes	yes
103	yes	yes	no	no
104	yes	yes	yes	yes
105	no	yes	yes	yes
106	yes	no	yes	no
107	yes	no	no	no
108	yes	no	yes	no
109	yes	no	yes	no
110	yes	yes	no	no
111	yes	yes	no	no
112	yes	yes	yes	yes
113	yes	yes	yes	yes
114	yes			
115	yes	no	no	no
116	yes	yes	yes	yes
117	yes	yes	yes	yes
118	yes	yes	yes	yes
119	yes	yes	no	no
120	yes	no	yes	no
121	yes	no	no	no
122	yes	yes	yes	yes
123	yes	yes	yes	yes
124	yes	no	yes	no
125	yes	yes	no	no
126	yes	yes	yes	yes
127	yes	yes	yes	yes
128	yes	yes	yes	yes
129	yes	yes	yes	yes
130	no	yes	yes	yes
131	yes	yes	yes	yes
132	yes	yes	no	no
133	yes	yes	yes	yes
134	yes	yes	yes	yes
135	yes	no	yes	no
136	yes	no	no	no
137	yes	no	no	no
138	yes			
139	yes	yes	yes	yes
140	yes	yes	yes	yes
141	yes	yes	yes	yes
142	yes	yes	yes	yes
143	yes	yes	no	no
144	yes	no	no	no
145	yes	no	yes	no
146	no	yes	yes	yes
147	yes	yes	yes	yes
148	yes	yes	yes	yes
149	yes	yes	no	no
150	yes	no	no	no
151	yes	no	no	no

Case	chair_ stand_ completed	case_ found	low_ strength_ or_ performance	possible_ sarcopenia
152	no	no	yes	no
153	yes	yes	no	no
154	yes	yes	yes	yes
155	yes	yes	yes	yes
156	yes	yes	yes	yes
157	yes	yes	yes	yes
158	yes	yes	yes	yes
159	yes	yes	no	no
160	yes	yes	yes	yes
161	yes	yes	yes	yes
162	yes	yes	yes	yes
163	yes	yes	yes	yes
164	yes	yes	yes	yes
165	yes	no	yes	no
166	yes	yes	no	no
167	yes	yes	no	no
168	yes	yes	no	no

12.6 Plagiarism Certificate

[The plagiarism-check (similarity index) certificate is enclosed here.]

12.7 AI Detection Certificate