Kochi University

Development of a Modified Renal Function Assessment Using Calf Circumference as a Proxy for Muscle Mass in The Elderly

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Background

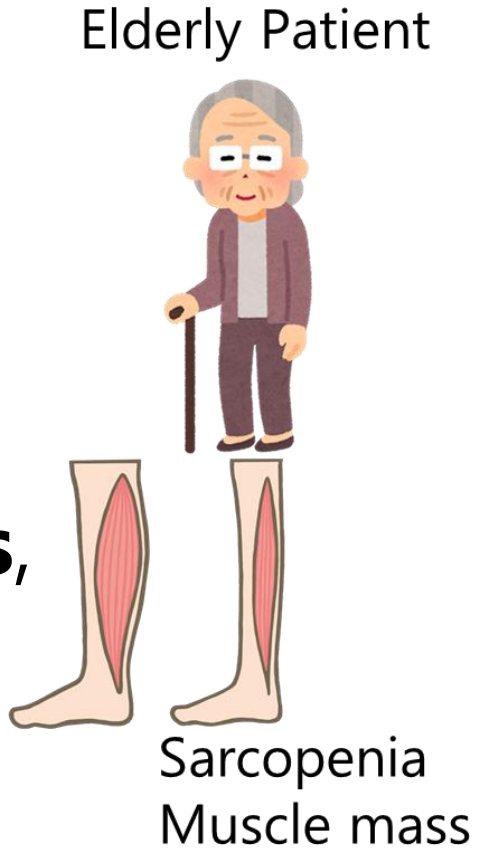
Overestimation of kidney function in the elderly with eGFRcr

- Measured creatinine clearance in the **bedridden/malnourished elderly** is ~**80%** of creatinine-based estimates.

Jpn J Geriat. 1988; 25: 503-507

- **15%** of elderly inpatients had renal **dosing errors**, with **95%** at **overdose risk.**

Fundamental & Clinical pharmacology.2017; 31: 110-119



Development modified eGFRcr equations incorporating markers for muscle mass

Bioelectrical impedance analysis (BIA)*1

○ Non-invasive

× Specialized equipment

Computed tomography (CT)*2

High precision

Expensive, Radiation

Arm circumference & Triceps skin fold *1

Low cost

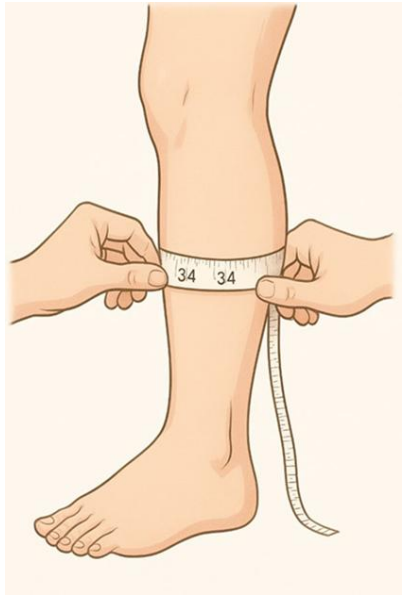
Measuring instruments

*1 *Int J Clin Pharmacol. 2019;57(5):229–239*

*2 *Clinical Kidney Journal. 2023;16(8):1265–1277*

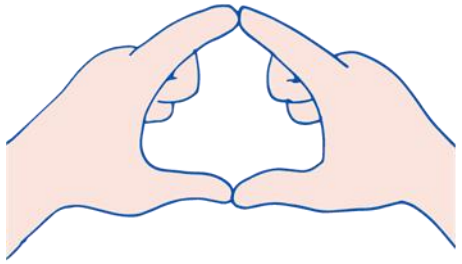
Lower leg circumference measurements

Calf circumference



- At the **widest point** of the non-dominant calf
- In a **seated position** using a **flexible tape**.

Finger ring test



- Encircling the calf with the patient's **own thumb and index finger.**

Geriatr Gerontol Int 2018; 18(2): 224-232

Aim of the study

- Develop a **modified eGFRcr** incorporating **lower-leg circumference** for **easier use in daily clinical practice**.

Methods

Study design & Setting

- A **prospective multicenter cohort** study
  Derivation study
- Four **Community hospitals** in Japan.
- November 2023 to October 2025.

PICOT

Patients	**Elderly** inpatients
Index test	**Modified eGFRcr**
Comparison	**eGFRcr**
Outcome	**Accuracy of GFR estimation**
Target condition	24-hour creatinine clearance **(CCr24)***

* CCr24 = measured CCr24 × 0.715

Patients

▼ Inclusion criteria:

- **Non-bedridden** in-patient ≥ **60 years**, regardless of comorbidity
- Capable of 24-hour urine collection / Indwelling urinary catheter

▼ Exclusion Criteria

- Serum creatinine level **≥2.0 mg/dL,**
- 24-hour urine output **less than 500 ml**
- Use of medications that interfere with creatinine metabolism

(trimethoprim, cimetidine, spironolactone, probenecid)

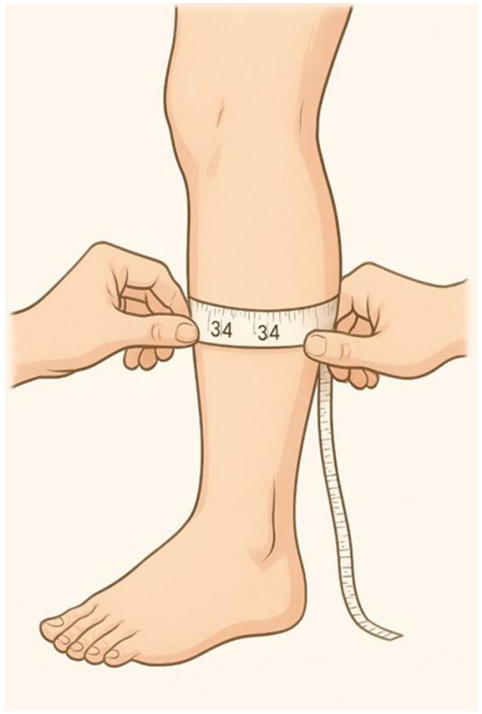
- Severe **lower leg edema**

(a depression mark that does not recover within 15 seconds after finger pressure).

Med Sci Monit 2019 Jan 1;25:1-9

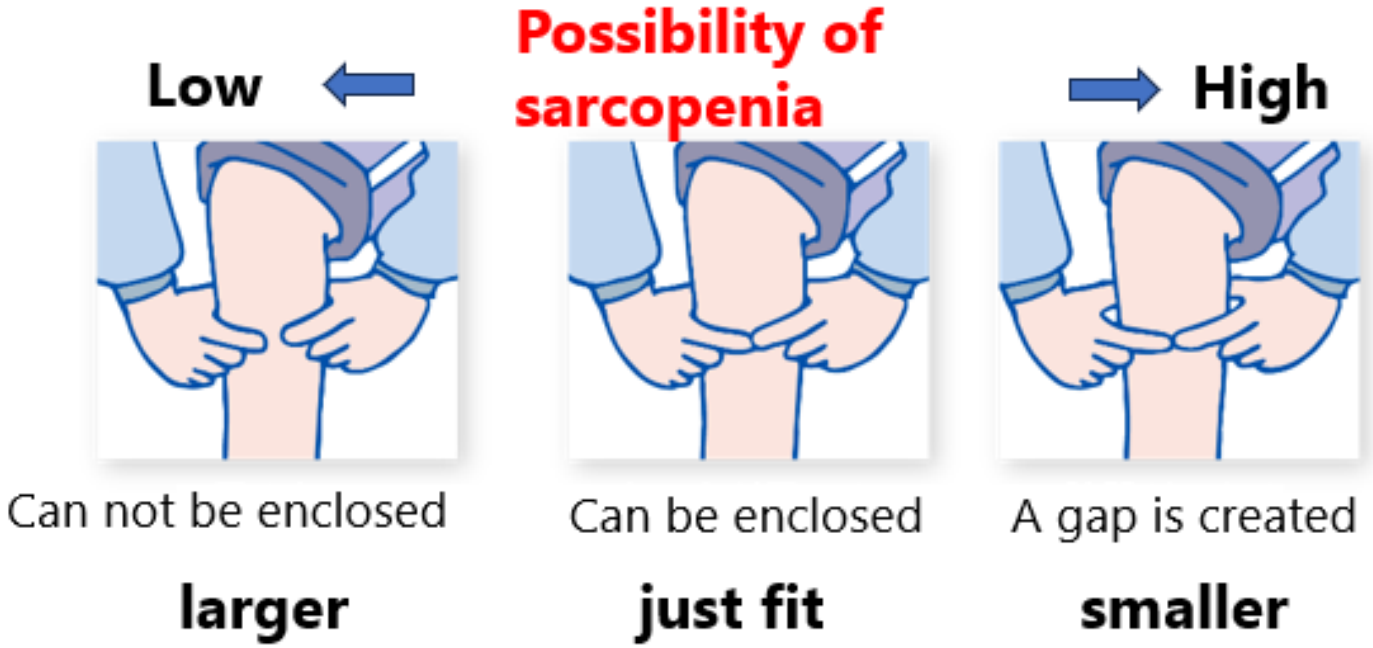
Incorporation of lower leg circumference measurements

1.Calf circumference



cm

2. Finger ring test



Classified into two categories

“Smaller”

“Just fit or Larger”

Statistical analysis
- model development & validation -

1. **Model development**: Linear regression analysis
   ①Basic model: eGFRcr
   ②Extended models: **Model 1　eGFRcr + calf circumference**
   Model 2　eGFRcr + finger ring test
2. **Performance evaluation**
   - Discrimination (CCr24 < 45 ml/min/1.73m^2)　: ROC curve & AUC
   - Calibration: calibration plot: R^2, RMSE, calibration slope, calibration-in-the-large(CITL)
3. **Internal validation:** Bootstrap

Results

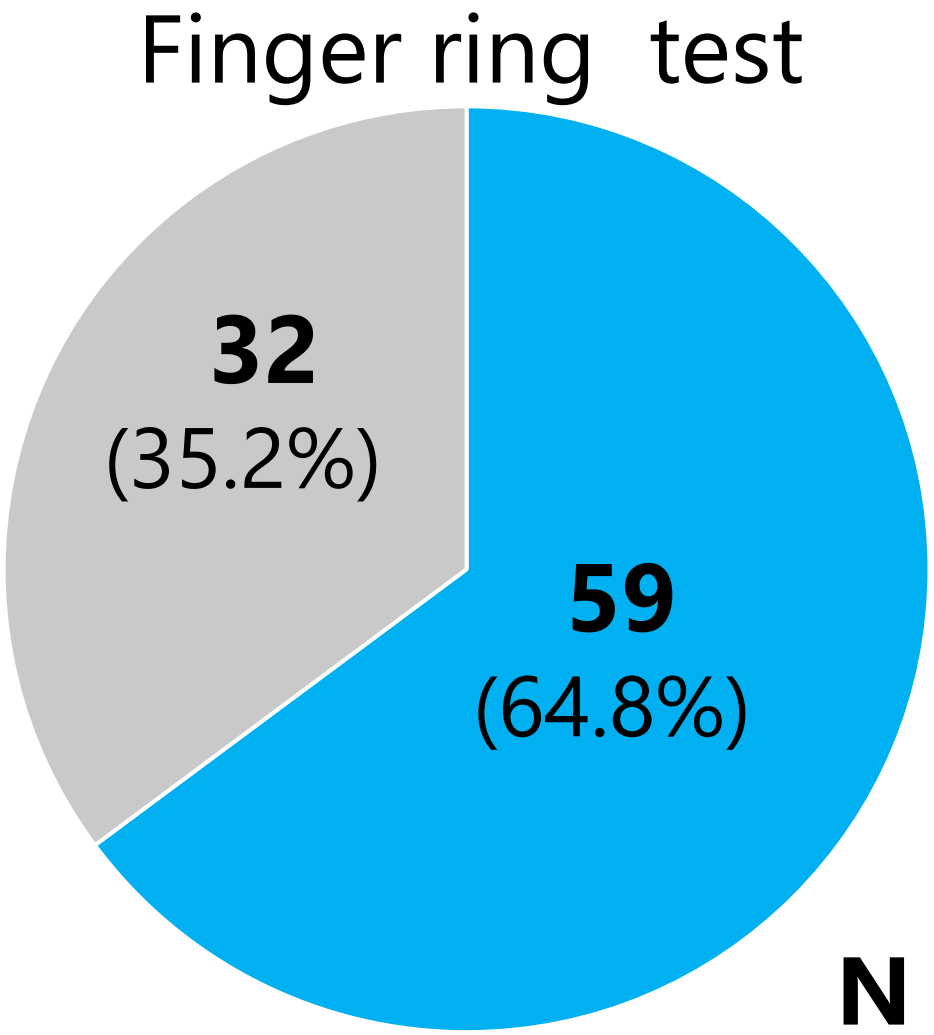
Patient characteristics N=91

Median (IQR)

	Male n=32	Female n=59
Age (years)	**78 (70–85)**	**81.5 (75–88)**
Serum creatinine (mg/dL)	0.9 (0.8–1.1)	0.8 (0.6–1.1)
24hr Urine volume (ml)	1200 (1000–1950)	1225 (825–1600)
eGFRcr (ml/min/1.73m^2)	**62.8 (53.5–73.0)**	**49.7 (39.0–69.4)**
CCr24* (ml/min/1.73m^2)	**48.6 (35.0–66.4)**	**30.0 (29.9–57.6)**

IQR, interquartile range. * CCr24 = measured CCr24 × 0.715

Lower leg circumference measurements



N = 91

Female (n= 58)

Median 31 cm (IQR: 28–33)

Male (n= 33)

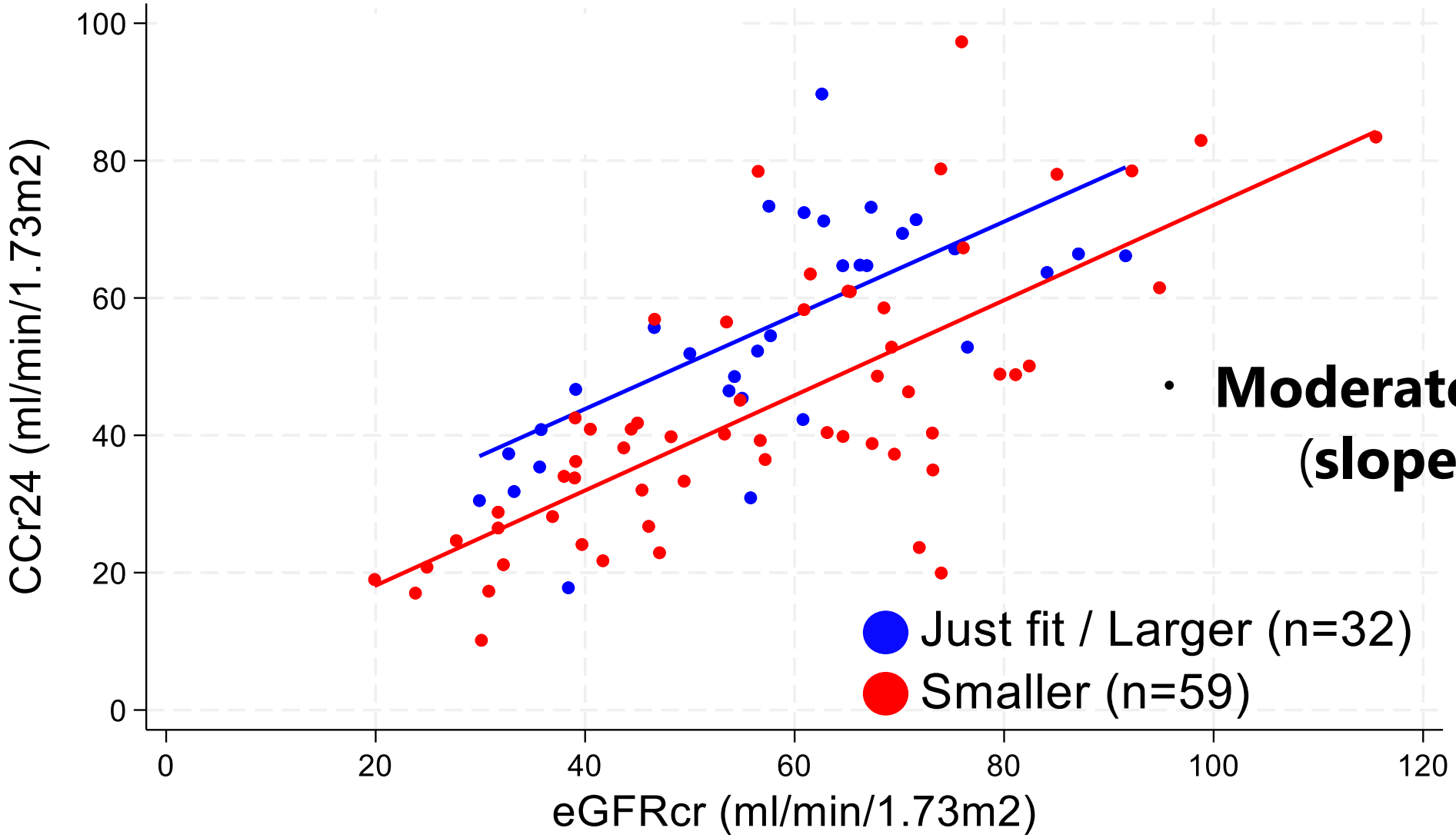
Median 31 cm (IQR: 29–34)

IQR, interquartile range.

Smaller

Just fit & Larger

Scatter plot and regression line
- Finger ring test-



- **Moderate** correlation (**slope ≈ 0.69**)

Regression models

- **Model 1:** calf (cm) · · · · · · · **Lower leg circumference**

  CCr24 = -43.53 + 0.7 × eGFRcr + 1.67 × calf

  R^2 = 0.557

  Root MSE = 13.31

- **Model 2:** finger ring test (0, 1) · · **0: just fit or larger, 1: smaller**

  CCr24 = 16.1 + 0.69 × eGFRcr – 11.68 × ring-test

  R^2 = 0.535

  Root MSE = 13.63

Quick reference chart (predicted CCr24)
- Finger ring test-

	Smaller n=59	Just fit / Larger n=32
eGFRcr (ml/min/1.73m²)	**Predicted CCr24** (ml/min/1.73m²)	**Predicted CCr24** (ml/min/1.73m²)
30	25	37
45	35	47
60	45	58
90	66	78

※ CKD Stage G1 G2 G3a G3b

eGFRcr(ml/min/1.73m²) 90≤ 60~89 45~59 30~44

Quick reference chart (predicted CCr24)
- Finger ring test-

	Smaller n=59	Just fit / Larger n=32
eGFRcr (ml/min/1.73m²)	**Predicted CCr24** (ml/min/1.73m²)	**Predicted CCr24** (ml/min/1.73m²)
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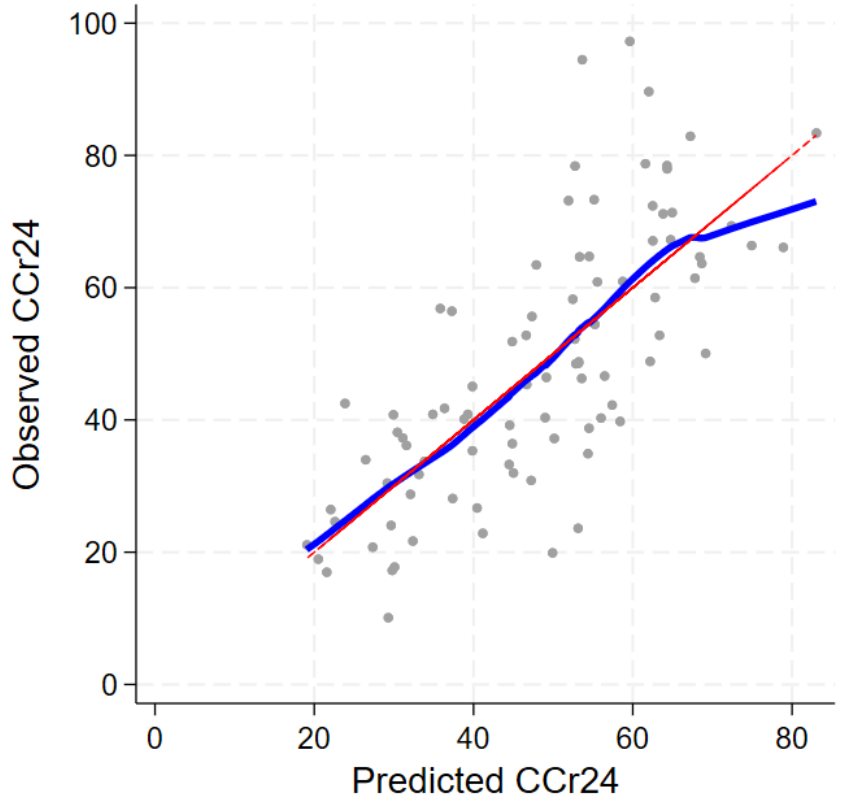
※ CKD Stage G1 G2 G3a G3b

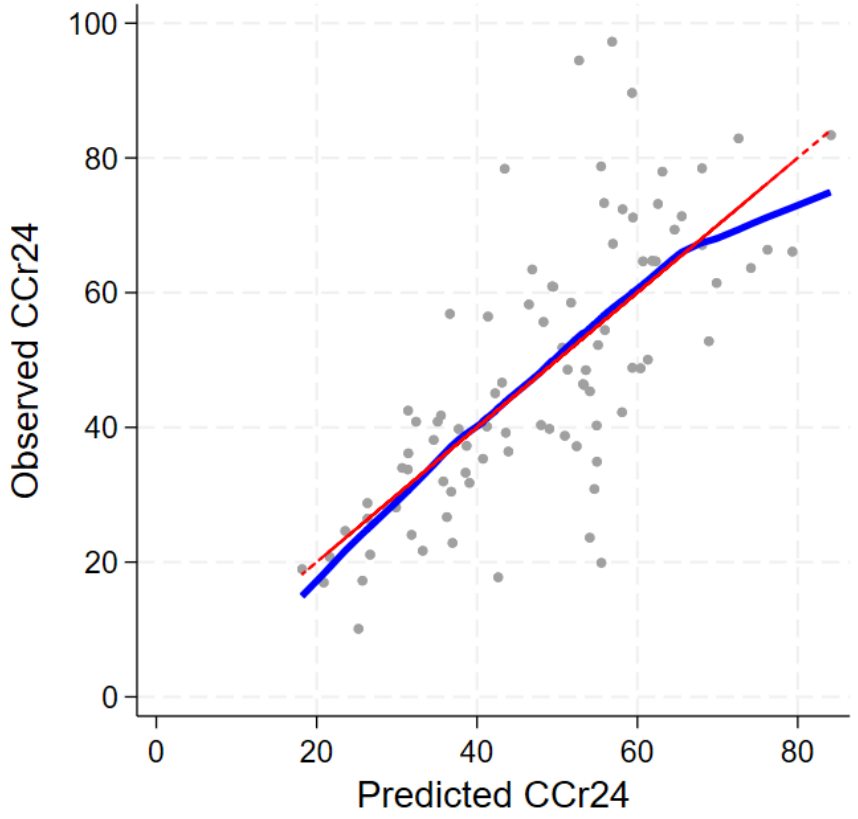
eGFRcr(ml/min/1.73m²) 90≤ 60~89 45~59 30~44

Calibration plot for continuous outcome (CCr24)

Model 1: calf circumference



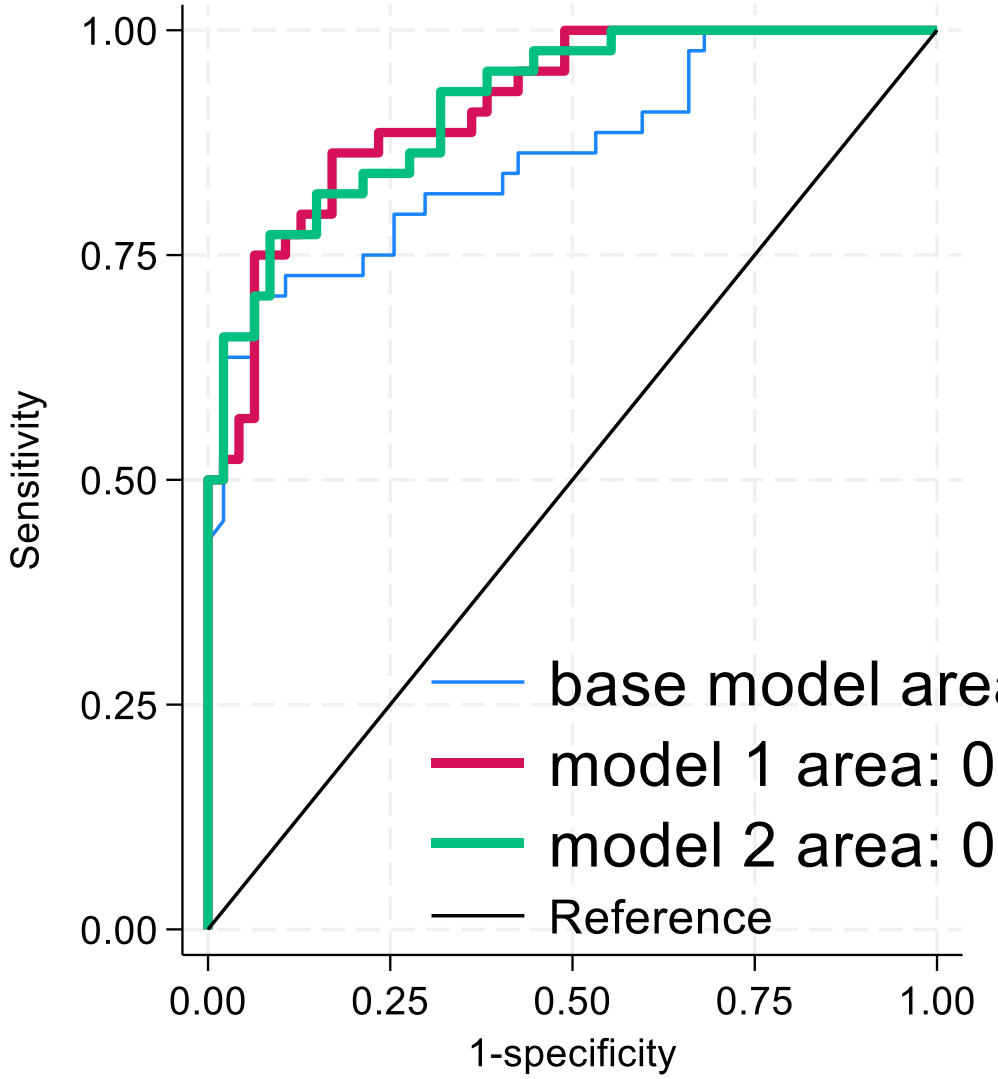
Model 2: finger ring test



- Excellent calibration achieved (**Slope ≈ 1.0, CITL ≈ 0**) Strong predicted-observed agreement with minimal bias **(bootstrap validated)**

CITL: calibration-in-the-large

ROC / AUC comparison
(CCr24 < 45ml/min/1.73m²)



- Both models demonstrated **excellent discrimination**.
- **No significant difference** in AUC
- Model 2 slightly higher, but the difference is negligible.

CI: bootstrap confidence interval

Improved detection of kidney dysfunction by developed predictive models

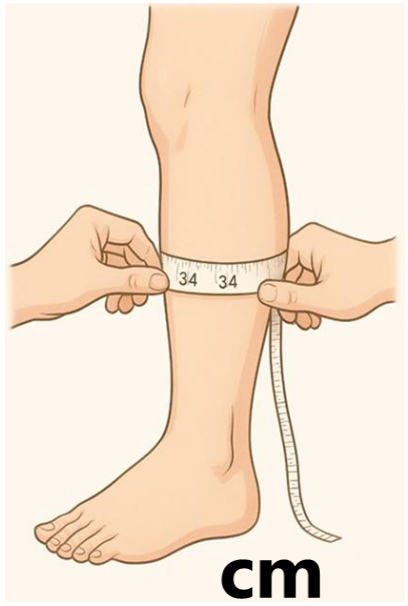
	CCr24 (ml/min/1.73m^2)	
(ml/min/1.73m^2)	< 45 (n = 44)	≥ 45 (n = 47)
eGFRcr		
< 45 (n = 26)	25	1
≥ 45 (n = 65)	19	46
Model 1 (eGFRcr + calf circumference)		
< 45 (n = 38)	34	4
≥ 45 (n = 53)	10	43
Model 2 (eGFRcr + finger ring test)		
< 45 (n = 39)	34	5
≥ 45 (n = 52)	10	42
total	44	47

Improved detection of kidney dysfunction by developed predictive models

	CCr24 (ml/min/1.73m^2)	
(ml/min/1.73m^2)	< 45 (n = 44)	≥ 45 (n = 47)
eGFRcr		
< 45 (n = 26)	**25 (56.8%)**	1
≥ 45 (n = 65)	19	46 (97.9%)
Model 1 (eGFRcr + calf circumference)		
< 45 (n = 38)	**34 (77.3%)**	4
≥ 45 (n = 53)	10	43 (91.5%)
Model 2 (eGFRcr + finger ring test)		
< 45 (n = 39)	**34 (77.3%)**	5
≥ 45 (n = 52)	10	42 (89.5%)
total	44	47

Conclusion

- Adding lower-leg circumference to eGFRcr
  → May reduce overestimation in the elderly with low muscle mass



OR