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Correlation Between Intrinsic Capacity and Muscle Strength and Quality in Older Patients with Cardiovascular Disease: A Cross-Sectional Study

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Background: Cardiovascular disease (CVD) has become the leading cause of death worldwide. High muscle mass can reduce the incidence and mortality of CVD. In recent years, increasing attention has been given to the relationship between intrinsic capacity (IC) and CVD. This study aims to explore the relationship between the decline of IC, muscle strength, and muscle quality in older patients with CVD, providing a new method and basis for early recognition of IC decline in the older adults.
Methods: This cross-sectional study included 475 older individuals from communities in Zhejiang. General data were collected, and a comprehensive geriatric assessment (CGA) was conducted. Participants with CVD were divided into three groups: IC retention, IC impairment, and IC significantly impaired. Bioelectrical impedance analysis (BIA) measurements were completed. Student's *t*-test or non-parametric tests (Mann–Whitney) were used to analyze the correlation between IC and muscle-related indicators. The best cutoff values were obtained using ROC curve analysis.
Results: Compared to non-CVD patients, CVD patients were older, more educated, and had higher rates of polypharmacy and comorbidity. IC decreased more significantly in CVD patients. Age (P=0.001), Fried (P=0.024), and GDS-5 (P=0.002) increased with the severity of IC decline. ADL (P=0.002), MMSE (P=0.000), MNA-SF (P=0.000), SARC-Calf (P=0.026), waist circumference (P=0.037), and muscle quality (P=0.010) decreased with the decline in IC. When IC decreased, the cutoff values for hand grip strength, waist circumference, and muscle quality were 25.45 kg, 72.55 cm, and 3.05, respectively. When IC decreased significantly, the cutoff values were 17.15 kg, 71.55 cm, and 2.28, respectively.
Conclusion: The results of this study showed that in patients with CVD, the hand grip strength and muscle quality of patients with IC injury were lower than those of patients with IC retention.
Keywords: CVD, intrinsic capacity, muscle quality

Introduction

With the continuous development of the economy and advancements in the medical system, the average life expectancy of humans is increasing, leading to significant changes in the global population structure. Currently, global population aging has become a major issue that all countries need to address. As the population ages, the incidence of cardiovascular disease (CVD) continues to rise, making it the world's leading cause of death.[1] This presents a major challenge for global public health. CVD not only severely impacts patients' quality of life but also imposes a substantial economic burden on the medical system.[2] Therefore, it is particularly important to study the related factors of CVD in the older adults population. Research has shown that higher muscle mass is associated with a lower

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incidence and mortality of CVD.[3] Individuals with higher muscle density tend to have a lower risk of CVD[4], which can enhance the prediction of adverse outcomes.[5] Additionally, decreased muscle strength is considered an independent risk factor for CVD in the older adults.[6] Previous studies have shown that abdominal obesity is closely related to CVD and is a stronger risk factor than BMI.[7]

In recent years, the relationship between intrinsic capacity (IC) and CVD has garnered increasing attention. The World Health Organization (WHO) introduced the concept of IC in its Global Report on Aging and Health, defining it as the composite of all physical and mental capacities that an individual can draw upon at any given time.[8] IC encompasses five domains: cognitive, sensory, vitality, psychological, and locomotor.[9] Ramirez highlighted that IC impairment is significantly associated with CVD morbidity and mortality.[10] Studies have shown that IC impairment leads to adverse outcomes such as falls, frailty, and readmission, which affects the quality of daily life of the older adults and increases the burden on the family.[11,12] Research by Jotheeswaran et al indicated that IC can predict the occurrence of adverse events, underscoring the importance of early identification of IC decline.[13]

Currently, the relationship between IC and muscle-related indicators (muscle strength, muscle mass, muscle quality) in older patients with CVD is not well understood. This study aims to explore the relationship between IC decline and muscle strength and muscle quality in older patients with CVD, providing a new method and basis for future evaluations of IC decline in the older adults.

Methods

Study Population

This was a cross-sectional study that collected 475 older adults from communities in the Zhejiang region of China who completed our questionnaire as well as somatic function measurements between February 2023 and April 2024 and underwent body identity component measurements. The participants' medical reports were used to assess whether they had CVD. Inclusion criteria were age ≥60 years; completion of all comprehensive geriatric assessment surveys. Exclusion criteria were older adults who were unable to complete the questionnaires, such as those with hearing and vision difficulties.

Comprehensive Geriatric Assessment

All patients completed the CGA,[13,14] which involved an investigation of disease and medication history. Questionnaires including Mini-Mental state examination (MMSE), activities of daily living (ADL), mini-nutrition assessment short-form (MNA-SF), 5-time chair stand test, 5-item geriatric depression scale (GDS-5) and Sarcopenia Assessment Form (SARC-CalF) were completed.

Intrinsic Capacity

Intrinsic capacity consists of five domains: cognitive, sensory, vitality, psychological, and locomotor. Locomotor ability was evaluated using the 5-time chair stand test, with a time of ≥12 seconds recorded as 1 point. Cognitive ability was measured by the Mini-Mental State Examination (MMSE), a tool widely used in clinical evaluations of cognitive impairment. Different standards were applied based on educational backgrounds, with cognitive impairment scored as 1 point. The Mini Nutritional Assessment-Short Form (MNA-SF) was used to assess vitality; higher scores indicate better nutritional status. A score of ≥11 points was assessed as a decrease in vitality, recorded as 1 point. The psychological domain was evaluated using the Geriatric Depression Scale-5 (GDS-5), where a score of ≥2 was recorded as positive, counting as 1 point. The sensory domain of IC was evaluated through self-reported visual and auditory impairments, with a total possible score of 2 points. The total IC evaluation score was 6 points. In this study, we divided IC into three groups: the IC normal group (IC score 0), the IC impairment group (IC score 1–3), and the IC significantly impaired group (IC score 4–6).

Muscle Quality

In this study, we defined the ratio of hand grip strength to skeletal muscle mass index as "muscle quality". Hand grip strength was measured using a grip strength meter. Each hand was measured twice, with a 5-minute interval between measurements, and the maximum hand grip strength value was recorded. The skeletal muscle mass index was derived from muscle mass measurements obtained via bioelectrical impedance analysis (BIA) using the InBody S10 device (Korea). To ensure the highest accuracy of the data, all participants refrained from wearing metal jewelry during the BIA measurement and were in a resting state throughout the process.

Statistical Analysis

Statistical analysis was conducted using SPSS 26.0. Quantitative variable distributions were assessed using the Kolmogorov–Smirnov test. Normally distributed quantitative data were expressed as mean ± standard deviation. Non-normally distributed quantitative data were expressed as median (interquartile range) [M (Q1, Q3)]. Proportional data were described using composition ratios, and comparisons between groups were made using the chi-squared ($\chi2$) test. We incorporated all variables into the heatmap analysis and obtained the results through Spearman's rank correlation analysis. Differences between quantitative variables were analyzed using Student's *t*-test and nonparametric tests (Mann–Whitney) for variables that did not follow a normal distribution. Factors with $P < 0.05$ in the non-parametric test were used to determine the optimal cut-off value via the subject operating curve (ROC) and Youden index, and the area under the ROC curve (AUC) was used to estimate their discriminatory power. A P-value < 0.05 was considered statistically significant.

Result

Patient Characteristics

Of the 475 baseline participants (median age 79 years), 325 (68.4%) had CVD. All participants were divided into CVD group (n=325) and non-CVD group (n=150). The study found that compared with patients with non-CVD, patients with CVD were older, more educated, more polypharmacy and comorbidity in the older adults, and IC decreased more significantly. The above P < 0.05, were statistically significant. See Table 1 for details.

Cross-Sectional Analysis of IC Grouping

For participants in the CVD group, we performed body composition analysis after excluding older individuals (n=85) who had metal implants (such as stents, fracture plates, pacemakers) that were not suitable for BIA examination. All subjects were divided into three groups: IC normal group (n=12), IC impairment group (n=173), and IC significantly

Table 1 Baseline Characteristics

	Total(n=475)	CVD(n=325)	Non-CVD(n=150)	P
Age, y	79(73,86)	79(73,86)	77(72,83)	0.004*
Male, n (%)	183(38.5)	130(40.0)	53(35.3)	0.331
Height, cm	158(152,165)	158(153,165)	157(150,163)	0.037*
Weight, kg	58(50.0,65.0)	59(50.0,65.0)	56(50.0,64.5)	0.396
BMI, kg/m^2	23.2(20.7,25.3)	23.1(20.5,25.3)	23.4(20.9,25.0)	0.551
Education level, n (%)				0.001**
Illiteracy	132(27.8)	71(21.8)	61(40.7)	
Primary	110(23.2)	82(25.2)	28(18.7)	
Junior high	98(20.6)	75(23.1)	23(15.3)	
Senior high	68(14.3)	50(15.4)	18(12.0)	
University or above	67(14.1)	47(14.5)	20(13.3)	
Married, n (%)	272(57.3)	144(44.3)	54(36.0)	0.069
Living alone, n (%)	105(22.1)	72(22.2)	33(22.0)	0.970
Smoking, n (%)	51(10.7)	36(11.1)	15(10.0)	0.725
Drinking, n (%)	90(18.9)	60(18.5)	30(20.0)	0.691
Comorbidity, n (%)	241(50.7)	224(68.9)	17(11.3)	0.000**
Polypharmacy, n (%)	82(17.3)	75(23.1)	7(4.7)	0.000**

(*Continued*)

Table 1 (Continued).

	Total(n=475)	CVD(n=325)	Non-CVD(n=150)	P
IC score, n (%)				0.038*
0	43(9.1)	21(6.5)	22(14.7)	
1	117(24.6)	78(24.0)	39(26.0)	
2	137(28.8)	101(31.1)	36(24.0)	
3	98(20.6)	65(20.0)	33(22.0)	
4	60(12.6)	45(13.8)	15(10.0)	
5	15(3.2)	10(3.1)	5(3.3)	
6	5(1.1)	5(1.5)	0(0.0)	
HGS of left, kg	20.9(15.3,26.2)	20.4(14.8,25.9)	21.3(17.2,26.9)	0.079
HGS of right, kg	21.9(16.1,27.1)	21.7(15.7,26.7)	22.4(17.4,27.7)	0.189
CC of left, cm	32.5(30.5,34.5)	32.5(30.0,35.0)	32.7(30.9,34.5)	0.635
CC of right, cm	32.5(30.5,35.0)	32.5(30.5,35.0)	32.9(31.0,35.0)	0.513

Notes: *P<0.05; **P<0.001.
Abbreviations: BMI, body mass index; IC, intrinsic capacity; HGS, hand grip strength; CC, calf circumference.

impaired group (n=55). The results showed statistically significant differences in age, GCA assessment, maximum hand grip strength, waist circumference, and muscle quality (P<0.05). Age (P=0.001), Fried score (P=0.024), and GDS-5 score (P=0.002) increased as IC decreased. Conversely, ADL (P=0.002), MMSE (P=0.000), MNA-SF (P=0.000), SARC-Calf (P=0.026), waist circumference (P=0.037), and muscle quality (P=0.010) decreased with the decline in IC. There were no significant differences in BMI, CC, SMM, and SMI in this study (P>0.05). See Table 2 for details.

Predicted Decline in IC

Figure 1 illustrates the correlation analysis between IC and various factors. The values in the IC column represent the correlation between each factor and IC; a negative value indicates that as the value of that factor decreases, the IC score increases, meaning that the IC gradually declines. The closer the value is to −1, the stronger the relationship between the

Table 2 Descriptive Cross-Sectional Analysis of IC

	Total(n=240)	Group 1(n=12)	Group 2(n=173)	Group 3(n=55)	P
Age, y	82.0±7.9	72.5±8.5	82.0±7.8	84.0±7.0	0.001*
BMI, kg/m^2	22.7±3.5	23.4±2.5	22.9±3.4	22.2±4.0	0.233
ADL, n(M (Q1,Q3))	100(90,100)	100(96,100)	100(95,100)	95(90,100)	0.002*
Fried, n(M (Q1,Q3))	1(1,2)	1(0,1)	1(1,2)	2(1,3)	0.024*
GDS-5, n(M (Q1,Q3))	0(0,1)	0(0,0)	0(0,1)	0(1.2)	0.002*
MMSE, n(M (Q1,Q3))	24(18,27)	25(24,27)	25(19,28)	19(16,23)	0.000**
MNA-SF, n(M (Q1,Q3))	12(11,14)	14(13,14)	13(11,14)	11(10,12)	0.000**
SARC-CalF, n(M (Q1,Q3))	10(2,12)	10(3,11)	10(1,12)	12(3,13)	0.026*
CC, cm	32.0±3.1	32.5±2.4	32.0±3.1	31.5±3.1	0.672
HGS, kg	20.5±7.9	24.3±10.3	20.5±7.6	17.1±7.4	0.013*
SMM, n(M (Q1,Q3))	21.8(19.3,26.0)	21.0(18.5,25,3)	21.9(19.7,26.3)	20.5(17.7,24.7)	0.079
SMI, n(M (Q1,Q3))	6.6(5.9,7.7)	6.5(5.8,7,1)	6.7(6.2,7.9)	6.3(5.5,7.5)	0.167
WC, n(M (Q1,Q3))	72.8(67.7,80.6)	80.0(73.5,84.9)	72.6(67.8,80.3)	71.4(66.4,79.1)	0.037*
MQ	3.0±1.0	3.0±1.1	3.1±1.0	2.8±1.0	0.010*

Note: *P<0.05; **P<0.001.
Abbreviations: Group 1, IC normal group; Group 2, IC impairment group; Group 3, IC significantly impairment group; BMI, body mass index; ADL, activities of daily living; Fried, fried frailty phenotype; GDS-5, 5-item geriatric depression scale; MMSE, mini-mental state examination; MNA-SF, short-form mini nutritional assessment; SARC-CalF, the SARC-F combined with calf circumference; CC, calf circumference; HGS, hand grip strength; SMM, skeletal muscle mass; SMI, skeletal muscle mass index; WC, waist circumference; MQ, muscle quality.

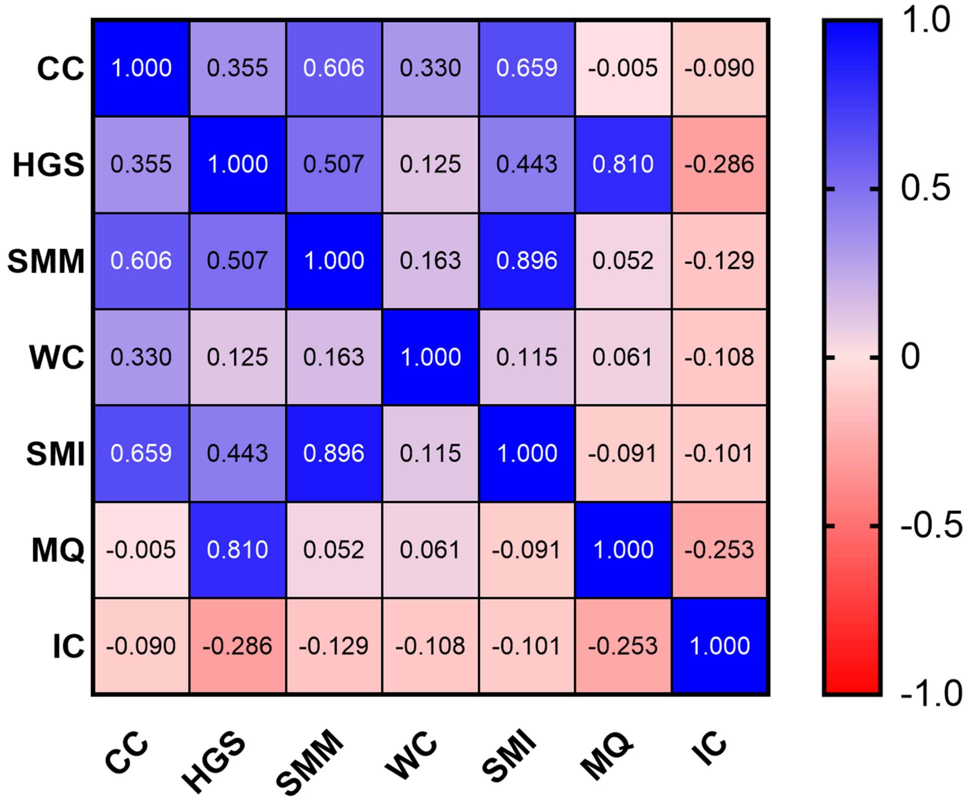

Figure 1 Heatmap of the correlation between IC and various factors.
Abbreviations: CC, calf circumference; HGS, hand grip strength; SMM, skeletal muscle mass; SMI, skeletal muscle mass index; WC, waist circumference; MQ, muscle quality.

variable and the decline in IC. Through the heatmap, we can see that muscle quality and grip strength have the strongest relationship with the decline in IC.

The Relationship Between IC Decline and Grip Strength, Waist Circumference, Muscle Quality

We grouped the factors (hand grip strength, waist circumference, muscle quality) with $P < 0.05$ in the non-parametric test according to IC for ROC analysis. The results are as follows.

IC Normal Group and IC Impairment Group

Figure 2 shows the ROC analysis of hand grip strength, waist circumference and muscle quality in IC normal group and IC impairment group. The results showed that the hand grip strength cutoff value was 25.45 kg (95% CI:0.434–0.771, P=0.237, AUC=0.602). The cut-off value of waist circumference was 72.55 cm (95% CI:0.594–0.812, P=0.019, AUC=0.703). The cut-off value of muscle quality was 3.05 (95% CI:0.565–0.835, P=0.021, AUC=0.700).

IC Impairment Group and IC Significantly Impairment Group

Figure 3 shows the ROC analysis of hand grip strength, waist circumference and muscle quality in IC impairment group and IC significant impairment group. The results showed that the hand grip strength cut-off value was 17.15 kg (95% CI:0.524–0.697, P=0.014, AUC=0.610). The cut-off value of waist circumference was 71.55 cm (95% CI:0.446–0.630, P=0.400, AUC=0.538). The cut-off value of muscle quality was 2.28 (95% CI:0.491–0.668, P=0.047, AUC=0.579).

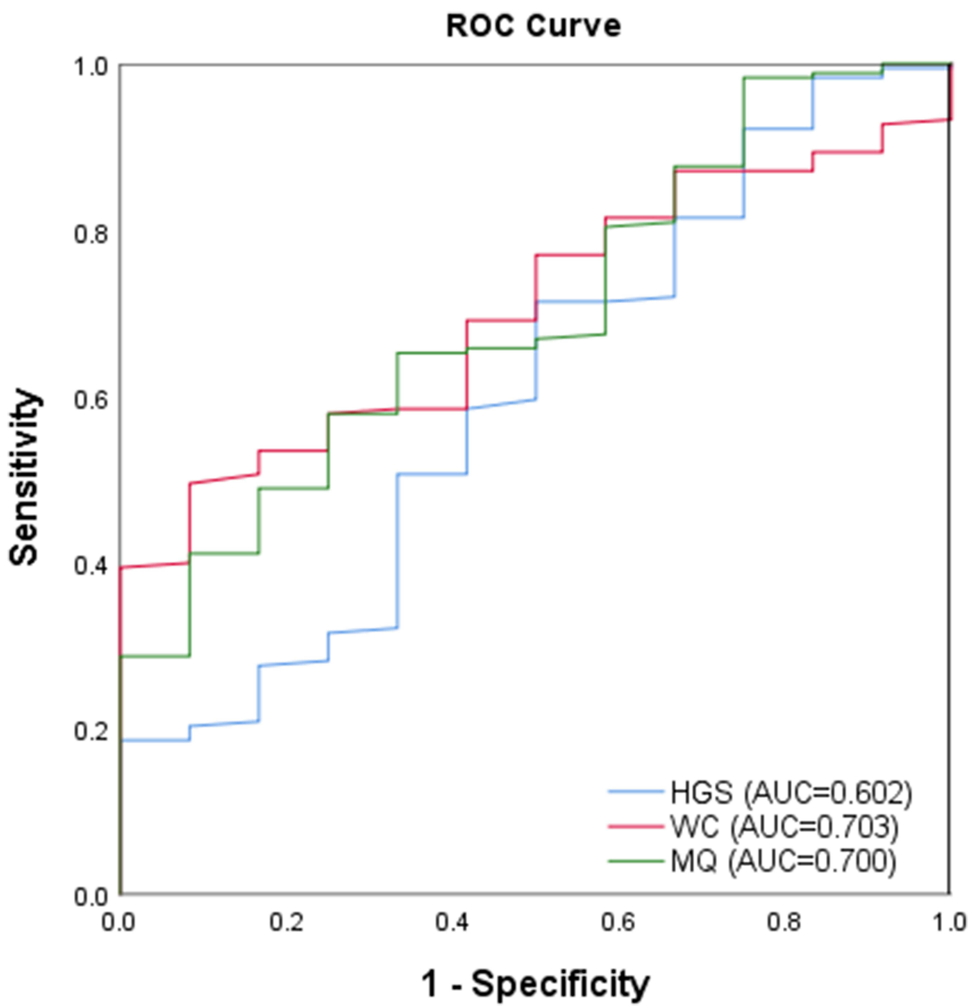

Figure 2 ROC for predicting IC impairment based on hand grip strength, waist circumference, and muscle quality.
Abbreviations: HGS, hand grip strength; WC, waist circumference; MQ, muscle quality.

Discussion

The prevalence of CVD in the older adults is increasing year by year, making it one of the leading causes of death worldwide. Consequently, the prevention and treatment of CVD are of paramount importance. Our results showed that IC decreased more significantly in patients with CVD, and polypharmacy and comorbidity were more common among the older adults. Therefore, we believe that reducing the number of medications in older patients, actively treating age-related diseases, and controlling or delaying the decline of IC in the older adults would be beneficial to their health.[15,16] According to ICOPE, IC reflects the overall function of the older adults, including five aspects: cognitive, sensory, vitality, psychological and locomotor.[17] The results of this study suggest that aging may be a risk factor for IC decline. With the increase of age, the physiological functions of the older adults have decreased, which leads to the decline of the overall function of the older adults. Our study found that a decrease in IC leads to a reduction in the activities of daily living in the older adults, which is consistent with the findings of Charles.[18]

Currently, the clinical screening of muscle mass primarily uses the SARC-CalF scale, which we also included in our study for analysis. The results showed that IC impairment was related to the SARC-CalF score (P=0.026). Previous studies have found that patients with decreased IC have an increased risk of falls, possibly due to insufficient muscle support in the lower limbs, resulting in a higher SARC-CalF score. This may explain our study's findings. Arokiasamy pointed out that hand grip strength is an important index to measure muscle strength and has a strong ability to predict IC decline.[19] Our study similarly found that hand grip strength decreased in both the IC impairment group and the IC

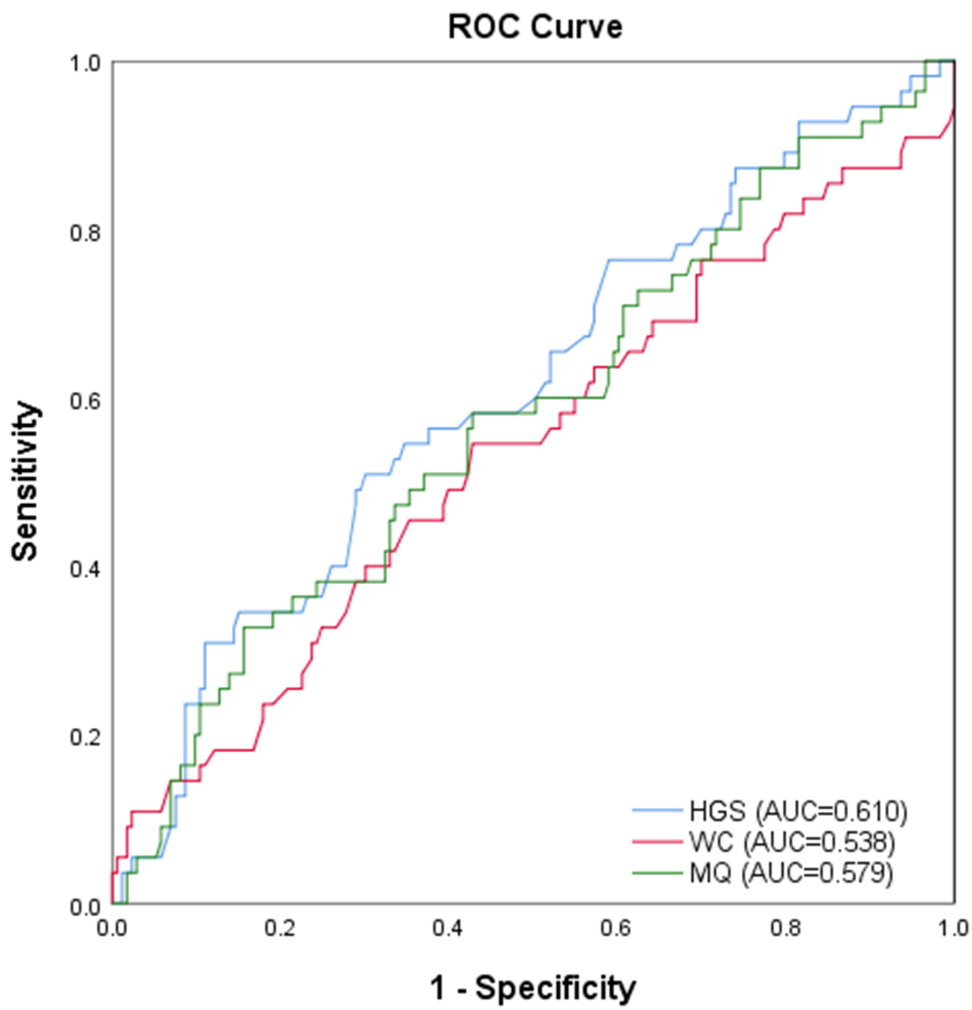

Figure 3 ROC for predicting IC significantly impairment based on hand grip strength, waist circumference, and muscle quality.
Abbreviations: HGS, hand grip strength; WC, waist circumference; MQ, muscle quality.

significantly impaired group compared to the IC normal group (P=0.013), consistent with previous research. Previous studies have shown that there is a strong correlation between muscle mass and hand grip strength.[20] Pedro further analyzed the relationship between muscle weakness and grip strength and found that the use of body-standardized muscle strength and bilateral asymmetric grip strength had higher diagnostic value for muscle, which also inspired us to include standard quantified muscle mass in future studies.[21,22] Furthermore, we analyzed the relationship between IC and skeletal muscle mass (SMM) and skeletal muscle mass index (SMI), but found no statistically significant difference, which may be attributed to the small sample size of the IC normal group. Waist circumference, a risk prediction tool for CVD, was also included in the analysis.[23] The waist circumference data in this study is derived from Inbody S10, which reduces the measurement error. The study found that IC decreased, waist circumference also decreased, the difference was statistically significant (P=0.037). Therefore, it is essential to monitor indicators such as muscle strength and waist circumference in the older adults population, as this may help to identify IC impairment early.

In clinical practice, we have observed that some patients experience a decrease in muscle mass without a corresponding significant decrease in muscle strength. Similarly, our study found no significant difference between IC impairment and skeletal muscle mass. Therefore, we introduced the concept of "muscle quality", which combines muscle mass and muscle strength.[24] Our data analysis results indicate that IC decline is related to muscle quality, showing a negative correlation between IC score and muscle strength (P=0.010). We also determined the cut-off values for hand grip strength, waist circumference, and muscle quality. Upon conducting an in-depth correlation analysis of all

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contributing factors with IC scores, it has been revealed that grip strength and muscle quality stand out as robust predictors of IC injury. In addition, we also determined the cut-off values for hand grip strength, waist circumference, and muscle quality.

Currently, the evaluation of IC is relatively complex, involving extensive content and requiring significant time, which is not conducive to large-scale implementation. Muscle mass measurement is more convenient than IC questionnaire evaluation and is thus more suitable for large-scale screening and early identification of IC decline. For primary care hospitals that do not have access to muscle mass measurement devices, we advise utilizing grip strength and waist circumference as effective screening tools for identifying IC decline. Notably, grip strength emerges as a more reliable predictor in this context. When hand grip strength is less than 25.45 kg or waist circumference is less than 72.55 cm, clinicians should be alert to the potential decline in IC.

Strengths and Limitations of This Study

In this study, we defined the specific calculation method of muscle quality and explored the relationship between IC and muscle quality, which has never been done before. We also studied the relationship between waist circumference and IC. However, we also acknowledge some limitations. First of all, the sensory field of IC factors is mainly through self-reporting, and errors are inevitable Secondly, the sample size of IC normal group is small, which may lead to bias and affect the final results. Finally, this study is a cross-sectional study, lacking follow-up data and unable to infer the causal relationship between IC and muscle quality.

Conclusions

The results of this study showed that in patients with CVD, the hand grip strength and muscle quality of patients with IC injury were lower than those of patients with IC retention. It is particularly noteworthy that grip strength and muscle quality have demonstrated significant predictive advantages.

Ethics Approval and Consent to Participate

This study was approved by the Medical Ethics Committee of Zhejiang Provincial Hospital of Chinese Medicine(2023-KLS-398-02) and all the participants provided written informed consent to use their data.

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An unauthorized version of the Chinese MMSE was used by the study team without permission, however this has now been rectified with PAR. The MMSE is a copyrighted instrument and may not be used or reproduced in whole or in part, in any form or language, or by any means without written permission of PAR (www.parinc.com).

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no competing interests in this work.

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