DOI: https://doi.org/10.22516/25007440.936

Original article

Factors associated with muscle mass and strength in patients with liver cirrhosis: A cross-sectional study

Juan David Vélez-Aguirre,[1*] Ismael de Jesús Yepes-Barreto.[2]

OPEN ACCESS

Citation:
Vélez-Aguirre JD, Yepes-Barreto IJ. Factors associated with muscle mass and strength in patients with liver cirrhosis: A cross-sectional study. Revista. colomb. Gastroenterol. 2022;37(4):410-419. https://doi.org/10.22516/25007440.936

[1] Pharos, Research group in Science, Technology and Health. Faculty of Medicine, Universidad de Cartagena. Cartagena, Colombia.
[2] Clinical Research Center Gastropack. Cartagena, Colombia.

***Correspondence:** Juan David Vélez-Aguirre.
jdavidze@outlook.com

Received: 08/07/2022
Accepted: 27/09/2022

Abstract

Introduction: Sarcopenia is a frequent complication of cirrhosis and has been related to the progression of liver failure and increased complications, including mortality. This study aimed to determine the factors associated with muscle mass and strength in cirrhotic patients. **Materials and methods:** Cross-sectional, descriptive, analytical study. All adults who attended outpatient hepatology assessment with a diagnosis of liver cirrhosis were included. They underwent a nutritional examination that included anthropometric measurements, bioimpedanciometry, grip strength, and the Royal Free Hospital-Nutritional Prioritizing Tool (RFH-NPT) screening scale. A linear or logistic regression analysis was performed as appropriate. **Results:** 40 patients were included. The frequency of malnutrition was 17.5%, according to grip strength. The main determinants of muscle mass in the multivariate linear analysis were age, total body protein value, and total body water. Grip strength was also a significant predictor in univariate linear regression. Variables related to decreased muscle strength were the Child-Pugh score, history of ascites and hepatic encephalopathy, consumption of ammonium-lowering therapies, RFH-NPT score, and fat-free mass. **Conclusions:** The skeletal muscle mass of the cirrhotic patient was associated with age, changes in body composition, and grip strength. The muscle strength determinants were the disease's stage, the consumption of ammonium-lowering therapies, and the score on the RFH-NPT scale.

Keywords

Sarcopenia, hepatic cirrhosis, nutritional assessment, muscular strength.

INTRODUCTION

Sarcopenia is a common complication of cirrhosis and has been associated with the progression of liver failure and an increased rate of complications, including mortality[(1)]. Despite its manifest clinical importance, the risk factors related to decreased muscle mass and strength in cirrhotic patients have been poorly evaluated.

In addition to the fact that no method is superior to the others, assessing this group of patients is still controversial[(1)]. Among the available tools, grip strength has emerged as a simple, low-cost, and effective method to detect malnutrition in cirrhotic patients, which adequately predicts the incidence of major complications, the need for transplantation, and mortality compared to some clinical indices[(2)].

This study used different nutritional assessment methods, including grip strength, to determine the factors associated with muscle mass and strength in cirrhotic patients in our setting.

MATERIALS AND METHODS

A cross-sectional, descriptive, analytical study was carried out. Convenience sampling was defined. The population consisted of patients older than 18 who attended follow-up with outpatient hepatology in a medical center in Cartagena

de Indias, Colombia, between January 2022 and March 2022. They had an unequivocal diagnosis of liver cirrhosis per clinical (signs of decompensation and laboratory findings or upper GI endoscopy [EGD] demonstrating esophageal varices), ultrasound (increased liver surface nodularity, increased liver echogenicity, right lobe atrophy, hypertrophy of the left or caudate lobes, decreased liver size, portosystemic shunts), elastographic (Baveno VI definition > 15 KPa regardless of etiology)[3], or pathological (liver biopsy with evidence of severe fibrosis or cirrhosis) criteria.

We excluded patients in whom factors associated with malnutrition were presumed (patients diagnosed with human immunodeficiency virus [HIV] infection, hepatocarcinoma, stage V chronic kidney disease, on renal replacement therapy, with cognitive impairment that prevented an adequate caloric intake, or who had used oral steroids chronically in the month before the tests) or who, due to some physical limitation, could not undergo any of the required tests of the study.

All study subjects were in a follow-up protocol that included screening for hepatocellular carcinoma[4] and esophageal varices with EGD, as proposed in Baveno VI[3]. The Calès[5] classification was used to describe esophageal varices. The etiological diagnosis of cirrhosis was made following current international clinical practice guidelines[6-12]. Cryptogenic cirrhosis was determined in those cases where it was impossible to decide on any attributable etiology. Subsequently, all the subjects were scheduled for a day of nutritional assessment, including measurement of weight, height, body mass index (BMI), corrected body mass index, bioimpedanciometry, mid-arm circumference (MAC), triceps skin fold (TSF), mid-arm muscle circumference (MAMC), and grip strength, determination of ascites and peripheral edema, and application of the Royal Free Hospital-Nutritional Prioritizing Tool (RFH-NPT) screening scale.

The InBody 270® Segmental Multifrequency DSM-BIA body composition analyzer was used to determine weight. Dry weight was calculated following the European Association for the Study of the Liver (EASL) clinical practice guidelines for nutrition in patients with chronic liver disease[1]. The DETECTO® PHR portable stadiometer was used, with an accuracy of ± 0.005 m for each measurement. Dry BMI was calculated using the formula: dry weight/(height)[2]. The cut-off scores proposed by Campillo et al. regarding malnutrition[13] were used for the corrected BMI.

An experienced physician measured the TSF (mm) and MAC (cm) on the non-dominant arm of each patient with a tape measure and caliper. Measurements were made at the midpoint between the acromion tip and the olecranon process, with the patient sitting in a relaxed position. The average of two consecutive measurements for each variable was recorded.

The MAMC (cm) was calculated according to the following formula: MAMC = MAC - (TSF * 0.314)[14]. The values were classified according to the TSF and MAMC tables standardized for age and sex proposed by Bishop et al. in 1981[15] (**Appendix 1**), and moderate and severe malnutrition were diagnosed according to Campillo et al.'s criteria[16]. According to the manufacturer's recommendations, a trained physician performed bioimpedance analysis with the InBody 270® body composition analyzer.

Grip strength was measured in the non-dominant arm. The average (in kilograms) of two consecutive measurements was reported. The results were compared with the reference values put forward by Budziareck et al. in 2008[17], and malnutrition was defined as a value below the 5th percentile according to age group and sex. The Jamar hydraulic dynamometer was employed to guarantee the comparability of the measurements.

An expert doctor filled out the RFH-NPT nutritional screening scale, which consists of a questionnaire of basic questions that include the patient's feeding route, the presence of acute hepatitis, the state of fluid overload, the dry BMI, the degree of unintentional weight loss, and any acute comorbidity that modifies dietary intake. Nutritional risk was calculated based on Borhofen et al.'s scores[18].

The results of each patient's laboratory examinations were recorded three months before the nutritional assessment date to calculate the disease's prognostic indices.

Statistical analysis

Quantitative and categorical variables were described using mean (standard deviation [SD]) and percentages, respectively. A logistic regression or linear regression analysis was used, as appropriate, to identify the factors associated with muscle mass and grip strength. Results were expressed as odds ratio (OR) or regression coefficients (B). A p less than or equal to 0.05 was considered statistically significant.

Ethical aspects

We complied with all the ethical regulations for research in humans under Colombian Resolution 8430 dated October 4, 1993, which qualifies the present investigation as of minimal risk since no intervention made was invasive. The institution's ethics committee designed, disseminated, and approved a written informed consent form. All patients freely and independently agreed to participate in the study.

RESULTS

Sample description

Forty patients with a previous diagnosis of liver cirrhosis were included. No diagnosis was made *de novo* since all the patients were referred from other institutions. The majority were women (65%), and the mean age was 66. The diagnosis was confirmed mainly by elastographic (72.5%) and ultrasound (17.5%) methods, and only four patients (10%) had the definitive anatomopathological study. The most common causes of advanced chronic liver disease were nonalcoholic steatohepatitis (NASH) cirrhosis in 42.5% (17 patients) and cryptogenic cirrhosis in 25% (ten patients) (**Table 1**).

So, 77.5% were classified as category A (31 patients) on the Child-Pugh prognostic scale, and 22.5% as category B (nine patients). None were category C. Also, 42.5% (17 patients) had a history of decompensation, and the leading causes were ascites in 35% (14 episodes) and hepatic encephalopathy in 25% (ten episodes); 50% (20 patients) had esophageal varices, of which 45% (nine patients) were large. The mean modified MELD score was 13.37 points (**Table 1**).

Regarding the anthropometric variables, the average BMI of the population was 27.36 kg/m^2, the skeletal muscle mass was 25.18 kg, and the average grip strength was 15.62 kg (**Table 2**).

Factors associated with skeletal muscle mass

Univariate linear regression found an association between skeletal muscle mass, male sex, and total body protein value. Grip strength also had a statistically significant relationship (b = 0.55; 95% confidence interval [CI]: 0.36-3.04; p = 0.0001) (**Table 3**).

Multivariate linear regression was performed with the variables that had a significant association with muscle mass in the univariate linear regression. Association was found with age, total body protein value, BMI, total body water, fat mass percentage, and fat-free mass. This analysis found no significant association between muscle strength and the male sex (**Table 4**).

Factors associated with muscle strength

Univariable linear regression was performed, noting that the main factors associated with muscle strength were male sex (b = 11.94; 95% CI: 8.5 to 15.3; p = 0.0001), age (b = -0.28; 95% CI -0.46 to -0.096; p = 0.004), chronic kidney disease (b = -6.11; 95% CI -10.92 to -1.31; p = 0.016), and fat-free mass (b = 4.01; 95% CI: 0.095 to 7.93; p = 0.045).

Table 1. Baseline characteristics of the patients

	Total sample n = 40
Age (years)	66 (4.58)
Average (SD)	
Identification	
- Women, n (%)	26 (65)
- Urban, n (%)	39 (97.5)
Personal history	
- High blood pressure, n (%)	18 (45)
- Type 2 diabetes mellitus, n (%)	15 (37.5)
- Chronic kidney disease, n (%)	6 (15)
- Smoking, n (%)	5 (12.5)
- Osteoporosis, n (%)	2 (5)
- Menopause*, n (%)	22 (84)
- History of ascites, n (%)	14 (35)
- History of hepatic encephalopathy, n (%)	10 (25)
- History of variceal bleeding, n (%)	4 (10)
Diagnostic information	
Etiology	
- NASH, n (%)	17 (42.5)
- Cryptogenic, n (%)	10 (25)
- AIH/PBC overlap, n (%)	4 (10)
- HCV infection, n (%)	3 (7.5)
- AIH, n (%)	3 (7.5)
- Alcoholic, n (%)	2 (5)
- SBC, n (%)	1 (2.5)
Varicose veins	
- Yes, n (%)	20 (50)
Varicose vein size	
- Small, n (%)	5 (25)
- Medium, n (%)	6 (30)
- Large, n (%)	9 (45)
Child-Pugh score	
- A, n (%)	31 (77.5)
- B, n (%)	9 (22.5)
- C, n (%)	0
- Modified MELD, n (%)	13.37 (1.16)

PBC: primary biliary cholangitis; SBC: secondary biliary cholangitis; AIH: autoimmune hepatitis; MELD: Model for End-stage Liver Disease; NASH: nonalcoholic steatohepatitis; HCV: chronic infection with the hepatitis C virus. Source: The authors.

Multivariate linear regression was performed with variables that had a significant association with muscle strength in univariate linear regression. In this analysis, male gender was the only independent predictor of muscle strength (b = 10.79; 95% CI 7.17 to 14.42; p = 0.0001).

Table 2. Results of nutritional assessment

Anthropometry	
Triceps fold (mm) Average (SD)	20.18 (3.88)
Mid-arm circumference (cm) Average (SD)	27.37 (1.46)
Mid-arm muscle circumference (cm) Average (SD)	21.03 (0.78)
Grip strength (kg) Average (SD)	15.62 (2.23)
Bioimpedancemetry	
Weight (kg) Average (SD)	74.21 (5.23)
Size (m) Average (SD)	1.65 (0.02)
BMI (m/kg^2) Average (SD)	27.36 (2.16)
Total body water (kg) Average (SD)	39.06 (3.24)
Bone mineral content (kg) Promedio (DE)	3.78 (0.36)
Body fat mass (kg) Average (SD)	19.37 (4.97)
Fat mass percentage (%) Average (SD)	25.18 (5.78)
Skeletal muscle mass (kg) Average (SD)	27.36 (2.80)
Fat-free mass (kg) Average (SD)	54.83 (4.80)
Total body protein (kg) Average (SD)	9.73 (0.91)
Muscular strength	
Normal, n (%)	33 (82.5)
Decreased, n (%)	7 (17.5)

Source: The authors.

Accordingly, the data on gender and age were analyzed based on Budziareck et al.'s tables[17]. The variables related to the decrease in muscle strength were the Child-Pugh score, history of ascites and hepatic encephalopathy, use of ammonium-lowering therapies, RFH-NPT score, and fat-free mass (**Table 5**).

Table 3. Univariable linear regression: skeletal muscle mass

Relationship of variables with skeletal muscle mass			
Univariable linear regression			
Variable	**B**	**CI**	***p***
Male sex	10.56	7.98 a 13.14	0.0001
Age	-0.205	-0.36 a -0.04	0.01
High blood pressure	2.49	-2.44 a 7.43	0.3
Type 2 diabetes mellitus	-1.23	-5.67 a 3.21	0.56
Chronic kidney disease	1.49	-4.70 a 7.68	0.61
Smoking	-1.07	-9.45 a 7.29	0.78
Osteoporosis	-4.4	-11.68 a 2.87	0.21
Menopause	-0.75	-6.69 a 5.18	0.79
History of ascites	0.57	-6.78 a 7.94	0.87
History of hepatic encephalopathy	-2.4	-10.79 a 5.98	0.55
History of variceal bleeding	1.57	-6.43 a 9.58	0.68
KDIGO classification of chronic kidney disease	-0.04	-0.11 a 0.02	0.22
Child-Pugh score	-0.02	-0.15 a 0.10	0.71
BMI	-0.03	-0.06 a -0.006	0.01
Bioimpedancemetry			
- Total body water	0.39	0.17 a 0.60	0.001
- Mineral	0.17	-0.04 a 0.39	0.11
- Body fat mass	-0.02	-0.06 a 0.009	0.13
- Body fat percentage	0.061	0.01 a 0.11	0.017
- Fat-free mass	-0.16	-0.24 a -0.07	0.0001
- Total body protein	2.43	2.07 a 2.8	0.0001
Anthropometry			
- TSF	-0.002	-0.009 a 0.005	0.57
- MAMC	0.024	-0.003 a 0.05	0.08
- Grip strength	0.55	0.36 a 0.74	0.0001
- RFH-NPT	-1.38	-5.82 a 3.047	0.52

MAMC: mid-arm muscle circumference; RFH-NPT: Royal Free Hospital-Nutritional Prioritizing Tool; TSF: triceps fold. Source: The authors.

Table 4. Multivariate linear regression: skeletal muscle mass

Relationship of variables with skeletal muscle mass			
Variable	B	CI	*p*
Male sex	0.13	-0.01 a 0.27	0.07
Age	-0.005	-0.009 a -0.001	0.01
BMI	-0.048	-0.07 a -0.02	0.001
Total body water	0.52	0.33 a 0.70	0.0001
Total body protein	2.22	1.89 a 2.54	0.0001
Body fat mass percentage	0.28	0.01 a 0.04	0.0001
Fat-free mass	-0.21	-0.29 a -0.14	0.0001

Source: The authors.

Malnutrition prevalence

Taking into account the scores obtained in the RFH-NPT, 40% (16 patients) had a moderate and high risk of malnutrition. Regarding the standardized MAMC tables proposed by Bishop et al.[15], 37.5% (15 patients) had some degree of malnutrition. Based on the age and sex tables by Budziareck et al.[17], 17.5% (seven patients) presented with decreased muscle strength. According to the IMCC, 15% (six patients) had malnutrition.

DISCUSSION

The present study identified that the main determinants of skeletal muscle mass in cirrhotic patients were male sex, age, BMI, total body water, fat mass percentage, fat-free mass, total body protein, and grip strength.

Few works have tried to answer this question. In 2019, a study conducted by Sung et al.[19] demonstrated that grip strength (<18 kg for women; <26 kg for men), age (>60 years), history of hepatic encephalopathy, and elevated levels of *Wisteria floribunda* agglutinin-positive mac-2-binding protein (WFA^+-M2BP > 1.86 COI; a recent marker of liver fibrosis)[20] were the main predictors of loss of skeletal muscle mass in a population of cirrhotic patients.

Another study by Hiraoka et al. concluded that increased Child-Pugh score and decreased serum albumin levels were the most critical risk factors associated with decreased muscle mass and strength in patients with chronic liver disease[21]. Our study found no significant relationship between serum albumin levels and muscle mass or strength.

Table 5. Univariate linear regression: muscle strength according to Budziareck et al.'s sex and age tables[17]

Regresión lineal univariable			
Variable	OR	CI	*p*
Male sex	3.06	0.57 a 16.30	0.189
Age	1.01	0.94 a 1.08	0.686
High blood pressure	1.81	0.34 a 9.40	0.48
Type 2 diabetes mellitus	1.31	0.25 a 6.87	0.74
Chronic kidney disease	2.9	0.41 a 20.27	0.283
Smoking	1.2	0.11 a 12.81	0.87
History of ascites	6.66	1.09 a 40.7	0.04
History of hepatic encephalopathy	6	1.05 a 34.14	0.04
Presence of varicose veins	8.1	0.87 a 75.47	0.06
KDIGO classification of chronic kidney disease	2.49	0.83 a 7.39	0.1
Ammonium-lowering therapy	6	1.05 a 34.14	0.04
Serum albumin	0.85	0.2 a 3.6	0.82
Child-Pugh score	7.46	1.26 a 44	0.02
BMI	1.2	0.98 a 1.5	0.07
Corrected BMI	0.93	0.09:9.50	0.95
Bioimpedancemetry			
- Skeletal muscle mass	1.06	0.93 a 1.20	0.35
- Body fat mass	1	0.92 a 1.08	0.97
- Body fat percentage	0.97	0.90 a 1.04	0.42
- Fat-free mass	1.08	1 a 1.18	0.05
- Total body protein	1.21	0.82 a 1.79	0.32
Anthropometry			
- TSF	1	0.91 a 1.09	0.98
- MAC	1.03	0.84 a 1.27	0.752
- MAMC	1.07	0.79 a 1.45	0.65
Scales			
- Nutritional status according to the MAMC	0.49	0.49 a 2.43	0.813
- RFH-NPT	5.69	1.09 a 29.71	0.039

Source: The authors.

Regarding the other results, the relationship found between muscle mass and total body water could be explained by the fact that the water content of skeletal muscle mass is approximately between 70% and 75%, causing the total body water volume to increase at the expense of intracellular water in skeletal muscle fibers[22].

It is striking that, in our results, a negative association was found between skeletal muscle mass and fat-free mass. It could be speculated that the greater free mass in these patients is determined by increased extracellular water due to the pathophysiological processes typical of advanced chronic liver disease[23].

We also could demonstrate a significant relationship between muscle mass and strength, whose indirect measurement through grip strength has been emerging in recent years as a cost-effective, non-invasive tool in the early identification of malnutrition in cirrhotic patients[24] and even as a predictor of mortality[25].

Our analysis revealed similar results for muscle strength to those reported in previous studies. Significant relationships were found with male sex, age, presence and severity of chronic kidney disease, and fat-free mass. Sex was the only independent predictor in multivariate linear regression.

A study conducted by Nishikawa et al. in 2021 observed that in men, the main determinants of muscle strength loss were age, diagnosis of cirrhosis, glomerular filtration rate, and the ratio of extracellular water to total body water. Meanwhile, in women, they were the diagnosis of cirrhosis, serum albumin concentrations, the albumin:bilirubin ratio, prothrombin time, platelet count, and the ratio of extracellular water to total body water [26].

Consequently, considering the apparent differences between the sexes concerning muscle strength under Budziareck et al.'s tables[17], the population was discriminated by sex and age. It was shown that the variables most closely related to muscle strength were the Child-Pugh score, history of ascites, history of hepatic encephalopathy, use of ammonium-lowering therapies, RFH-NPT score, and fat-free mass. Some of these factors, such as the Child-Pugh score and history of encephalopathy, were also reported in Sung et al.'[19] and Hiraoka et al.'[21] works.

The use of ammonium therapies was related to decreased muscle strength. This finding is not surprising and can be explained by the fact that currently, the indication for these therapies is limited to the management of overt encephalopathy and secondary prophylaxis to prevent recurrences[27], which implies more advanced stages of chronic liver disease.

The RFH-NPT scale has been correlated with clinical deterioration, the severity of the disease (according to the Child-Pugh and MELD scores), and the appearance of different clinical complications such as ascites, hepatorenal syndrome, and hepatic encephalopathy. In addition, its application is an independent predictor of clinical deterioration and transplant-free survival, and improvements in this scale are associated with improved survival[18]. The most recent EASL guidelines support its use[1]. Our study revealed that it is the only screening scale significantly associated with muscle strength, so it is a good tool for identifying cirrhotic patients at risk of malnutrition.

In the present study, the prevalence of malnutrition ranged between 15% and 40% depending on the method used. This reflected the need for more uniformity among the available instruments and expressed the need for precise tools that can be used in daily practice. All this, added to the heterogeneous groups included in the studies, the severity of the disease, the etiology of cirrhosis, and the comorbidities presented, makes the prevalence of malnutrition in the literature vary greatly: 10% to 100%(28).

Taking into account that in our study, grip strength was the only nutritional assessment tool significantly associated with muscle mass, it could be determined that the most accurate prevalence of malnutrition was 17.5%. The high prevalence evidenced by the RFH-NPT score (40%) does not diminish its validity but, on the contrary, positions it as a good screening tool with excellent sensitivity.

The other measurements used in the nutritional assessment of cirrhotic patients did not have a significant association with each other or with the RFH-NPT. Thus, our results do not support using any of them (IMCC, MAMC, TSF, MAC) in daily practice.

The main limitation of our study was the sample size, considering that the collection of patients was restricted by the coronavirus disease 2019 (COVID-19) pandemic. Besides, there are no standardized national tables for anthropometric measurements (MAC, TSF, MAMC) or the grip strength values used in this study. To adequately interpret the results, local tables should be designed that account for our population's characteristics.

The main strength is that it is the first study that comprehensively evaluates the nutritional status of cirrhotic patients in Latin America.

CONCLUSIONS

The skeletal muscle mass of the cirrhotic patient was mainly associated with age, changes in body composition, and grip strength.

The main determinants of muscle strength were the stage of the disease, the use of ammonium-lowering therapies, and the score on the RFH-NPT scale. The latter seems to be a helpful tool for screening the nutritional status of cirrhotic patients in daily practice.

APPENDIX 1

Standardized TSF and MAMC tables for age and sex proposed by Bishop et al. in 1981[15]

Baseline TSF values distributed by age in US men

Age group	Sample size	Estimated population	Mean	Percentile						
Age		Millions	mm	5th	10th	25th	50th	75th	90th	95th
18-74	5261	61.18	12.0	4.5†	6.0	8.0	11.0	15.0	20.0	23.0
18-24	773	11.78	11.2	4.0	5.0	7.0	9.5	14.0	20.0	23.0
25-34	804	13.00	12.6	4.5	5.5	8.0	12.0	16.0	21.5	24.0
35-44	664	10.68	12.4	5.0	6.0	8.5	12.0	15.5	20.0	23.0
45-54	765	11.15	12.4	5.0	6.0	8.0	11.0	15.0	20.0	25.5
55-64	598	9.07	11.6	5.0	6.0	8.0	11.0	14.0	18.0	21.5
65-74	1657	5.50	11.8	4.5	5.5	8.0	11.0	15.0	19.0	22.0

†Values are given in units of mm. Table prepared from data collected during NHANES I from 1971 to 1974.

Baseline TSF values distributed by age in US women

Age group	Sample size	Estimated population	Mean	Percentile						
Age		Millions	mm	5th	10th	25th	50th	75th	90th	95th
18-74	8410	67.84	23.0	11.0†	13.0	17.0	22.0	28.0	34.0	37.5
18-24	1523	12.89	19.4	9.4	11.0	14.0	18.0	24.0	30.0	34.0
25-34	1896	13.93	21.9	10.5	12.0	16.0	21.0	26.5	33.5	37.0
35-44	1664	11.59	24.0	12.0	14.0	18.0	23.0	29.5	35.5	39.0
45-54	836	12.16	25.4	13.0	15.0	20.0	25.0	30.0	36.0	40.0
55-64	669	9.98	24.9	11.0	14.0	19.0	25.0	30.5	35.0	39.0
65-74	1822	7.28	23.3	11.5	14.0	18.0	23.0	28.0	33.0	36.0

†Values are given in units of mm. Table prepared from data collected during NHANES I from 1971 to 1974.

MAMC reference values distributed by age in US men

Age group	Sample size	Estimated population	Mean	Percentile						
Age		Millions	cm	5th	10th	25th	50th	75th	90th	95th
18-74	5261	61.18	28.0	23.8†	24.8	26.3	27.9	29.6	31.4	32.5
18-24	773	11.78	27.4	23.5	24.4	25.8	27.2	28.9	30.8	32.3
25-34	804	13.00	28.3	24.2	25.3	26.5	28.0	30.0	31.7	32.9
35-44	664	10.68	28.8	25.0	25.6	27.1	28.7	30.3	32.1	33.0
45-54	765	11.15	28.2	24.0	24.9	26.5	28.1	29.8	31.5	32.6
55-64	598	9.07	27.8	22.8	24.4	26.2	27.9	29.6	31.0	31.8
65-74	1657	5.50	26.8	22.5	23.7	25.3	26.9	28.5	29.9	30.7

†Values are given in units of cm. Table prepared from data collected during NHANES I from 1971 to 1974.

MAMC baseline values distributed by age in US women

Age group	Sample size	Estimated population	Mean	Percentile						
Age		Millions	cm	5th	10th	25th	50th	75th	90th	95th
18-74	8410	67.84	22.2	18.4†	19.0	20.2	21.8	23.6	25.8	27.4
18-24	1523	12.89	20.9	17.7	18.5	19.4	20.6	22.1	23.6	24.9
25-34	1896	13.93	21.7	18.3	18.9	20.0	21.4	22.9	24.9	26.6
35-44	1664	11.59	22.5	18.5	19.2	20.6	22.0	24.0	26.1	27.4
45-54	836	12.16	22.7	18.8	19.5	20.7	22.2	24.3	26.6	27.8
55-64	669	9.98	22.8	18.6	19.5	20.8	22.6	24.4	26.3	28.1
65-74	1822	7.28	22.8	18.6	19.5	20.8	22.5	24.4	26.5	28.1

†Values are given in units of cm. Table prepared from data collected during NHANES I from 1971 to 1974.

REFERENCES

1. EASL Clinical Practice Guidelines on nutrition in chronic liver disease. J Hepatol. 2019;70(1):172-93. https://doi.org/10.1016/j.jhep.2018.06.024
2. Alvares-da-Silva MR, Reverbel da Silveira T. Comparison between handgrip strength, subjective global assessment, and prognostic nutritional index in assessing malnutrition and predicting clinical outcome in cirrhotic outpatients. Nutrition. 2005;21(2):113-7. https://doi.org/10.1016/j.nut.2004.02.002
3. de Franchis R. Expanding consensus in portal hypertension: Report of the Baveno VI Consensus Workshop: Stratifying risk and individualizing care for portal hypertension. J Hepatol. 2015;63(3):743-52. https://doi.org/10.1016/j.jhep.2015.05.022
4. Marrero JA, Kulik LM, Sirlin CB, Zhu AX, Finn RS, Abecassis MM, et al. Diagnosis, Staging, and Management of Hepatocellular Carcinoma: 2018 Practice Guidance by the American Association for the Study of Liver Diseases. Hepatology. 2018;68(2):723-50. https://doi.org/10.1002/hep.29913
5. Calès P, Zabotto B, Meskens C, Caucanas JP, Vinel JP, Desmorat H, et al. Gastroesophageal endoscopic features in cirrhosis. Observer variability, interassociations, and relationship to hepatic dysfunction. Gastroenterology. 1990;98(1):156-62. https://doi.org/10.1016/0016-5085(90)91305-P
6. Chalasani N, Younossi Z, Lavine JE, Charlton M, Cusi K, Rinella M, et al. The diagnosis and management of nonalcoholic fatty liver disease: Practice guidance from the American Association for the Study of Liver Diseases. Hepatology. 2018;67(1):328-57. https://doi.org/10.1002/hep.29367
7. Ghany MG, Morgan TR. Hepatitis C Guidance 2019 Update: American Association for the Study of Liver Diseases-Infectious Diseases Society of America Recommendations for Testing, Managing, and Treating Hepatitis C Virus Infection. Hepatology. 2020;71(2):686-721. https://doi.org/10.1002/hep.31060
8. Terrault NA, Lok ASF, McMahon BJ, Chang K-M, Hwang JP, Jonas MM, et al. Update on prevention, diagnosis, and treatment of chronic hepatitis B: AASLD 2018 hepatitis B guidance. Hepatology. 2018;67(4):1560-99. https://doi.org/10.1002/hep.29800
9. Mack CL, Adams D, Assis DN, Kerkar N, Manns MP, Mayo MJ, et al. Diagnosis and Management of Autoimmune Hepatitis in Adults and Children: 2019 Practice Guidance and Guidelines From the American Association for the Study of Liver Diseases. Hepatology. 2020;72(2):671-722. https://doi.org/10.1002/hep.31065
10. Crabb DW, Im GY, Szabo G, Mellinger JL, Lucey MR. Diagnosis and Treatment of Alcohol-Associated Liver Diseases: 2019 Practice Guidance From the American Association for the Study of Liver Diseases. Hepatology. 2020;71(1):306-33. https://doi.org/10.1002/hep.30866
11. Lindor KD, Bowlus CL, Boyer J, Levy C, Mayo M. Primary Biliary Cholangitis: 2018 Practice Guidance from the American Association for the Study of Liver Diseases. Hepatology. 2019;69(1):394-419. https://doi.org/10.1002/cld.874
12. Chapman R, Fevery J, Kalloo A, Nagorney DM, Boberg KM, Shneider B, et al. Diagnosis and management of primary sclerosing cholangitis. Hepatology. 2010;51(2):660-78. https://doi.org/10.1002/hep.23294

13. Campillo B, Richardet J-P, Bories P-N. Validation of body mass index for the diagnosis of malnutrition in patients with liver cirrhosis. Gastroenterol Clin Biol. 2006;30(10):1137-43. https://doi.org/10.1016/S0399-8320(06)73491-1
14. Tandon P, Low G, Mourtzakis M, Zenith L, Myers RP, Abraldes JG, et al. A Model to Identify Sarcopenia in Patients With Cirrhosis. Clin Gastroenterol Hepatol. 2016;14(10):1473-1480.e3. https://doi.org/10.1016/j.cgh.2016.04.040
15. Bishop CW, Bowen PE, Ritchey SJ. Norms for nutritional assessment of American adults by upper arm anthropometry. Am J Clin Nutr. 1981;34(11):2530-9. https://doi.org/10.1093/ajcn/34.11.2530
16. Campillo B, Paillaud E, Uzan I, Merlier I, Abdellaoui M, Perennec J, et al. Value of body mass index in the detection of severe malnutrition: influence of the pathology and changes in anthropometric parameters. Clin Nutr. 2004;23(4):551-9. https://doi.org/10.1016/j.clnu.2003.10.003
17. Budziareck MB, Pureza Duarte RR, Barbosa-Silva MCG. Reference values and determinants for handgrip strength in healthy subjects. Clin Nutr. 2008;27(3):357-62. https://doi.org/10.1016/j.clnu.2008.03.008
18. Sung JH, Uojima H, Hidaka H, Tanaka Y, Wada N, Kubota K, et al. Risk factors for loss of skeletal muscle mass in patients with cirrhosis. Hepatol Res. 2019;49(5):550-8. https://doi.org/10.1111/hepr.13308
19. Ito K, Murotani K, Nakade Y, Inoue T, Nakao H, Sumida Y, et al. Serum Wisteria floribunda agglutinin-positive Mac-2-binding protein levels and liver fibrosis: A meta-analysis. J Gastroenterol Hepatol. 2017;32(12):1922-30. https://doi.org/10.1111/jgh.13802
20. Hiraoka A, Michitaka K, Izumoto H, Ueki H, Kitahata S, Aibiki T, et al. Relative changes in handgrip strength and skeletal muscle volume in patients with chronic liver disease over a 2-year observation period. Hepatol Res. 2018;48(7):502-8. https://doi.org/10.1111/hepr.13051
21. Lorenzo I, Serra-Prat M, Yébenes JC. The Role of Water Homeostasis in Muscle Function and Frailty: A Review. Nutrients. 2019;11(8):1857. https://doi.org/10.3390/nu11081857
22. D'Amico G, Garcia-Tsao G, Pagliaro L. Natural history and prognostic indicators of survival in cirrhosis: a systematic review of 118 studies. J Hepatol. 2006;44(1):217-31. https://doi.org/10.1016/j.jhep.2005.10.013
23. Devapriya Rejeev, Nagaraja BS, Kiran S, Chaitra KR. Handgrip strength is a better tool for assessing early malnutrition than subjective global assessment in liver cirrhosis. Int J Heal Clin Res. 2021;4(13 SE-Articles):354-7.
24. Daphnee DK, John S, Vaidya A, Khakhar A, Bhuvaneshwari S, Ramamurthy A. Hand grip strength: A reliable, reproducible, cost-effective tool to assess the nutritional status and outcomes of cirrhotics awaiting liver transplant. Clin Nutr ESPEN. 2017;19:49-53. https://doi.org/10.1016/j.clnesp.2017.01.011
25. Nishikawa H, Yoh K, Enomoto H, Ikeda N, Takashima T, Aizawa N, et al. Predictors for Grip Strength Loss in Patients With Chronic Liver Diseases. In Vivo. 2021;35(1):363-71. https://doi.org/10.21873/invivo.12267
26. Vilstrup H, Amodio P, Bajaj J, Cordoba J, Ferenci P, Mullen KD, et al. Hepatic encephalopathy in chronic liver disease: 2014 Practice Guideline by the American Association for the Study of Liver Diseases and the European Association for the Study of the Liver. Hepatology. 2014;60(2):715-35. https://doi.org/10.1002/hep.27210
27. Borhofen SM, Gerner C, Lehmann J, Fimmers R, Görtzen J, Hey B, et al. The Royal Free Hospital-Nutritional Prioritizing Tool Is an Independent Predictor of Deterioration of Liver Function and Survival in Cirrhosis. Dig Dis Sci. 2016;61(6):1735-43. https://doi.org/10.1007/s10620-015-4015-z
28. Rivera Irigoin R, Abilés J. Soporte nutricional en el paciente con cirrosis hepática. Gastroenterol Hepatol. 2012;35(8):594-601. https://doi.org/10.1016/j.gastrohep.2012.03.001