

Association between Handgrip Strength and the Six-Minute Walk Test with Length of ICU and Hospital Stay in Patients Undergoing Surgery for Intra-Abdominal Cancers

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Abstract

Background and Objective: Intra-abdominal cancers are among the most common malignancies in Iran, and surgery remains the primary treatment for patients with advanced disease. Simple functional measures, such as handgrip strength (HGS) and six-minute walk distance (6MWD), may help predict postoperative outcomes. This study aimed to investigate the association between HGS and 6MWD with the length of intensive care unit (ICU) and hospital stays in patients undergoing surgery for intra-abdominal cancers.

Materials and Methods: This prospective cohort study was conducted between 2021 and 2022 at Ayatollah Taleghani Hospital in Tehran, Iran. A total of 260 patients with intra-abdominal malignancies who underwent surgery were enrolled. The sample size was initially calculated based on mortality; however, it was also adequate for analyzing length-of-stay outcomes. After obtaining written informed consent and confirming eligibility, HGS and the distance covered during the 6-minute walk test (6MWD) were measured preoperatively. Data were analyzed using SPSS version 25. Independent-samples t-tests, Mann-Whitney U tests, and linear regression analyses were employed for statistical analysis.

Results: Among men, patients with an HGS greater than 24.9 kg had significantly shorter ICU stays compared to those with lower HGS (effect size: Cohen's $d = 3.2$, $P < 0.001$). A similar association was observed among women using a cutoff value of 19.9 kg ($P < 0.001$, Cohen's $d = 2.9$). Higher HGS was also significantly associated with shorter hospital stays, with cutoff values of 26.9 kg for men and 19.75 kg for women (both $P < 0.001$). Similarly, patients with better functional capacity, defined as a 6MWD exceeding 414 m in men and 402 m in women, had significantly shorter ICU stays ($P < 0.001$). Only four patients required mechanical ventilation; therefore, the analysis of its association with extubation lacked sufficient statistical power and was considered exploratory.

Conclusions: HGS and 6MWD were significantly associated with the length of ICU and hospital stays following surgery for intra-abdominal cancers. These findings suggest that HGS and 6MWD may serve as simple, noninvasive, and readily available tools for predicting postoperative outcomes and identifying patients at increased risk of prolonged hospitalization. The main limitations of this study include the small number of mechanically ventilated patients, the single-center design, the lack of external validation of the proposed cutoff values, and the absence of survival analysis.

Keywords: Walk Test; Abdominal Neoplasms; Intensive Care Units; Length of Stay

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Background and Objective

Cancer arises from the uncontrolled proliferation of cells and results from complex interactions between genetic and environmental factors. Mutations in key regulatory genes disrupt the normal mechanisms controlling cell division, ultimately leading to malignant transformation. In addition to genetic susceptibility, environmental factors such as chemical carcinogens, ionizing radiation, viruses, and bacteria contribute to cancer development. Advances in molecular biology and biomedical research have substantially improved our understanding of the mechanisms underlying carcinogenesis and have enhanced the early diagnosis and treatment of cancer.^{1,2} Among all malignancies, intra-abdominal cancers are among the most prevalent and economically burdensome worldwide, with an increasing incidence reported both globally and in Iran.³⁻⁶

Several factors have been implicated in the development of intra-abdominal cancers, including *Helicobacter pylori* infection, unhealthy dietary habits, physical inactivity, chronic stress, advanced age, and a positive family history.^{5,6} Gastric cancer, in particular, is the second leading cause of cancer-related mortality worldwide,^{7,8} and is also the most common gastrointestinal malignancy in Iran.⁹ Surgical resection remains the primary treatment for patients with advanced intra-abdominal malignancies. However, major abdominal surgery is frequently associated with postoperative complications, including prolonged intensive care unit (ICU) and hospital stays, infectious complications, and the need for mechanical ventilation.^{10-14,17}

Mechanical ventilation is a crucial element of postoperative critical care for patients experiencing respiratory failure or impaired consciousness. Despite its life-saving role, prolonged mechanical ventilation is nonphysiological and can contribute to ventilator-induced lung injury as well as an increased risk of hospital-acquired infections.¹⁸⁻²⁰ Previous studies have demonstrated that delayed liberation from mechanical ventilation is associated with higher mortality rates and an increased incidence of pulmonary complications.²¹⁻²⁴ Consequently, identifying reliable predictors of

successful ventilator weaning remains an important clinical objective.

In recent years, increasing attention has been directed toward simple, noninvasive measures for preoperative functional assessment. Among these, handgrip strength (HGS) has emerged as a reliable indicator of skeletal muscle strength and nutritional status. HGS is easy to measure, safe, reproducible, inexpensive, and requires minimal equipment. Lower HGS values have consistently been associated with older age and female sex.^{25,26} Another widely used functional assessment is the six-minute walk test (6MWT), with the 6MWD serving as a practical and validated measure of cardiopulmonary endurance and overall functional capacity.²⁶⁻³⁵ Additionally, body composition assessment provides a noninvasive method for estimating lean muscle mass and fat mass and has been shown to be useful in predicting postoperative complications.³⁶⁻³⁸

To the best of our knowledge, no comprehensive study has investigated the association between HGS and 6MWD with postoperative ICU and hospital length of stay among patients undergoing surgery for intra-abdominal cancers in Iran. Therefore, the present study was designed to evaluate the relationship between preoperative HGS and 6MWD and the duration of ICU and hospital stays in patients undergoing surgery for intra-abdominal malignancies.

Materials and Methods

Study Design

The primary objective of this study was to investigate the association between HGS and 6MWD with the length of stay in the ICU and the hospital (primary outcomes). Secondary outcomes included all-cause mortality and the duration of mechanical ventilation. However, due to the small number of events, these secondary outcomes lacked sufficient statistical power for robust analysis and were therefore considered exploratory.

Study Setting

This prospective cohort study was conducted at Taleghani Hospital, a tertiary referral center affiliated with Shahid Beheshti University of Medical Sciences, Tehran, Iran. Patients were recruited from the Department

of Surgery between 2021 and 2022, and all functional assessments were performed at the Sports Medicine Unit of the same institution. To minimize measurement variability, all evaluations were conducted in an outpatient setting using standardized, calibrated equipment under consistent testing conditions.

Participants

The study population consisted of patients with pathologically confirmed intra-abdominal malignancies who were scheduled to undergo curative surgical resection.

Eligible participants were between 25 and 75 years of age, had a left ventricular ejection fraction (LVEF) greater than 35%, and had no history of fractures within the previous six months. Additional exclusion criteria included disabling osteoarthritis, congenital deformities of the pelvis or spine that could interfere with functional testing, peripheral neuropathy, and the presence of any metallic prosthesis. Patients with more than one confirmed primary malignancy or those unwilling to continue participation were excluded from the study.

Participants were selected using simple random sampling from all eligible patients. Written informed consent was obtained from all participants before enrollment and prior to any study-related assessments.

Variables

Baseline variables included age, sex, height, weight, body mass index (BMI), and cancer diagnosis. The primary exposure variables were HGS and the 6MWD, both assessed preoperatively.

The primary outcome measures were the duration of mechanical ventilation until successful liberation, length of stay in the ICU, and overall hospital length of stay. Thirty-one-day in-hospital mortality was recorded as a secondary safety outcome. Successful liberation from mechanical ventilation was defined as the discontinuation of invasive mechanical ventilation without the need for reintubation during the institution's standard post-extubation observation period.

Data Sources and Measurements

Demographic and clinical data were collected using standardized case report forms and hospital medical records.

HGS was measured by the same sports medicine specialist using a CONSTANT hand dynamometer. Measurements were obtained with the participant seated, the arm adducted alongside the trunk, the elbow flexed at 90°, and the forearm in a neutral position. Three measurements were obtained from each hand, with 30-second rest intervals between trials. The highest value (kg) was recorded for analysis.

The 6MWT was performed according to the standard protocol in the Sports Medicine Unit corridor. Prior to the test, blood pressure, heart rate, and peripheral oxygen saturation (SpO₂) were measured, and perceived fatigue and dyspnea were assessed using a 0–10 numeric rating scale. Participants were allowed to take brief rest periods during the test if necessary. To minimize measurement bias, standardized verbal encouragement was intentionally withheld. Upon completion, vital signs and self-reported symptom scores were reassessed, and the 6MWD, expressed in meters, was recorded as the primary outcome.

Height was measured without shoes using a wall-mounted stadiometer, and body weight was measured using a calibrated digital scale while participants wore light clothing. BMI was calculated by dividing weight in kilograms by height in meters squared (kg/m²).

Bias

To minimize measurement bias, all functional assessments were performed by the same trained evaluator using the same calibrated equipment. Preoperative assessments were conducted within a standardized time frame before surgery to reduce the influence of day-to-day physiological variations. Outcome measures were defined according to the institution's standardized clinical protocols to minimize information bias. Whenever feasible, data entry and coding were performed blinded to the study hypotheses. Selection bias was minimized through clearly defined inclusion and exclusion criteria and simple random sampling. Potential confounding variables, including age, sex, BMI, and cancer diagnosis, were considered in the statistical analyses.

Sample Size

Because the primary outcomes of the study—ICU and hospital length of stay—were continuous variables, the sample size was estimated using the formula for comparing two independent means. Based on data from previous studies involving patients undergoing surgery for intra-abdominal malignancies, the standard deviation of ICU length of stay was estimated to be approximately 2.0 to 2.5 days. Assuming a minimum clinically important difference (MCID) of 1 day in ICU length of stay between patients with low and high HGS, a two-sided significance level of 0.05, and 80% statistical power, the required sample size was calculated to be approximately 64 patients per group (128 participants in total).

To enhance the precision of the estimates and account for potential attrition, a total of 260 patients were enrolled, substantially exceeding the minimum required sample size. Upon study completion, a post hoc effect size analysis demonstrated large to very large effect sizes (Cohen's $d = 1.2$ – 3.2) for the primary outcomes, corresponding to an estimated statistical power exceeding 99%.

Statistical Analysis

Statistical analyses were performed using SPSS software, version 25 (IBM Corp., Armonk, NY, USA).

The distribution of continuous variables was assessed using the Shapiro–Wilk test. Variables with a normal distribution are presented as the mean $\pm$ standard deviation (SD), while non-normally distributed variables are reported as the median and interquartile range (IQR).

Comparisons between two independent groups were performed using the independent-samples t-test or the Mann–Whitney U test, as appropriate. Multivariable linear regression analysis was used to adjust for potential confounding variables. Additionally, Cohen's d was calculated and reported for all primary comparisons.

Associations between HGS and 6MWD with continuous outcomes, including ICU length of stay, hospital length of stay, and duration of mechanical ventilation, were evaluated using Pearson's or Spearman's correlation coefficients, as appropriate, along with simple linear regression analysis. Adjusted regression

models were then constructed by including age, sex, BMI, and cancer diagnosis as covariates to control for potential confounding factors.

Receiver operating characteristic (ROC) curve analysis was performed to evaluate the predictive performance of HGS and 6MWD for successful liberation from mechanical ventilation. The area under the curve (AUC) was calculated with 95% confidence intervals (CIs), and optimal cutoff values were determined using the Youden index.

All statistical tests were two-tailed, and a p -value of less than 0.05 was considered statistically significant. The small proportion of missing data was handled using complete-case analysis, and sensitivity analyses were performed to evaluate the robustness of the findings following exclusion of missing observations.

Ethical Considerations

The study protocol was conducted in accordance with the principles of the Declaration of Helsinki. Prior to enrollment, all participants received a detailed explanation of the study objectives and procedures, and written informed consent was obtained. Participant confidentiality was ensured through data coding and restricted access to study records. All functional assessments were performed using noninvasive procedures and posed no additional risk to the participants.

Results

Demographic and Anthropometric Characteristics

A total of 260 patients with intra-abdominal malignancies were included in this study, comprising 146 women (56.15%) and 114 men (43.85%).

The mean age of the participants was 59.4 ± 9.8 years. Overall, 10% of the patients were younger than 45 years, 87% were between 45 and 75 years old, and 3% were older than 75 years.

The mean BMI was 26.3 ± 3.4 kg/m², with 66.54% of patients having a BMI between 20 and 32 kg/m². Regarding body weight, 39.61% of participants weighed less than 60 kg, 43.46% weighed between 61 and 80 kg, and 16.93% weighed more than 80 kg.

The demographic and anthropometric characteristics of the study population are summarized in Table 1.

Table 1. Demographic and Anthropometric Characteristics of the Study Population

Variable	No.	Percentage (%)
Gender		
Female	146	56.15
Male	114	43.85
Total	260	100
Age		
45 > years	26	10.0
45–75 years	228	87.0
Over 75	6	3.0
Total	260	100
Body Mass Index (BMI)		
<20 kg/m ²	35	13.46
20–32 kg/m ²	173	66.54
>32 kg/m ²	52	20.0
Total	260	100
Weight		
<60 kg	103	39.61
61–80 kg	113	43.46
>80 kg	44	16.93
Total	260	100

Table 1 summarizes the baseline demographic and anthropometric characteristics of the study population, including sex distribution, age, BMI, and body weight. The majority of participants were female (56.2%), and 87.0% were aged between 45 and 75 years. The mean BMI was 26.3 ± 3.4 kg/m², indicating that, on average, the study population was classified as overweight. Additionally, 39.6% of participants weighed less than 60 kg.

Association Between HGS and ICU Length of Stay

Prior to the primary analyses, ROC curve analysis was performed to determine the optimal cutoff values for HGS. The optimal cutoff values were 24.9 kg for men and 19.9 kg for women (Figures 1 and 2).

A significant association was observed between HGS and ICU length of stay. Among male patients, the mean ICU length of stay was 0.34 ± 1.80 days for those with an HGS greater than 24.9 kg, compared to 0.68 ± 4.27 days for those with an HGS of 24.9 kg or less ($P < 0.001$). Similarly, among female patients,

the mean ICU length of stay was 0.44 ± 2.64 days for those with an HGS greater than 19.9 kg, compared to 0.76 ± 5.96 days for those with an HGS of 19.9 kg or less ($P < 0.001$) (Table 2). Overall, patients with higher HGS experienced significantly shorter ICU stays and were discharged earlier than those with lower HGS (Figures 3 and 4).

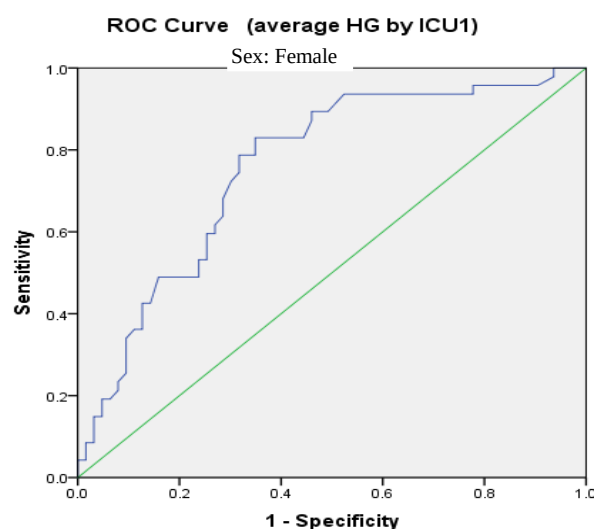


Figure 1. Receiver operating characteristic (ROC) curve analysis of handgrip strength (HGS) for predicting prolonged ICU length of stay in male patients. The optimal cutoff value was 24.9 kg.

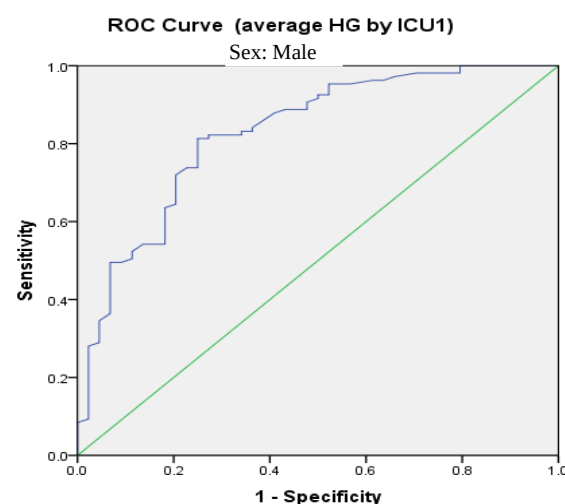


Figure 2. Receiver operating characteristic (ROC) curve analysis of handgrip strength (HGS) for predicting prolonged ICU length of stay in female patients.

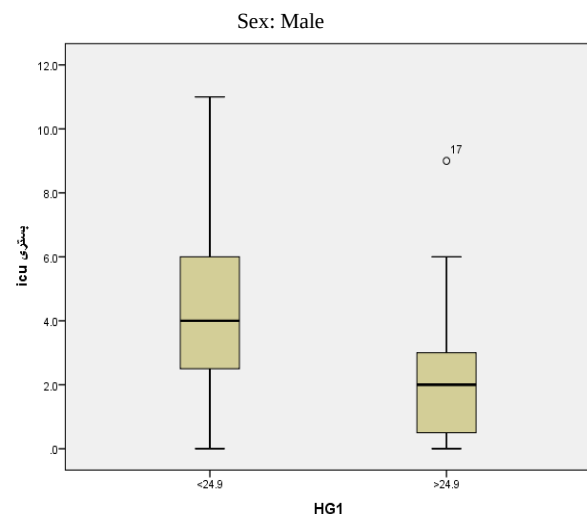


Figure 3. Comparison of ICU length of stay between male patients with handgrip strength (HGS) greater than 24.9 kg and those with HGS less than or equal to 24.9 kg.

Male patients with an HGS greater than 24.9 kg had a significantly shorter ICU length of stay compared to those with an HGS of 24.9 kg or less (approximately 1.8 vs. 4.3 days, $P < 0.001$; Cohen's $d = 3.2$). This substantial difference suggests that preoperative HGS may serve as a practical and readily available indicator for identifying male patients at increased risk of prolonged postoperative ICU stay following surgery for intra-abdominal malignancies.

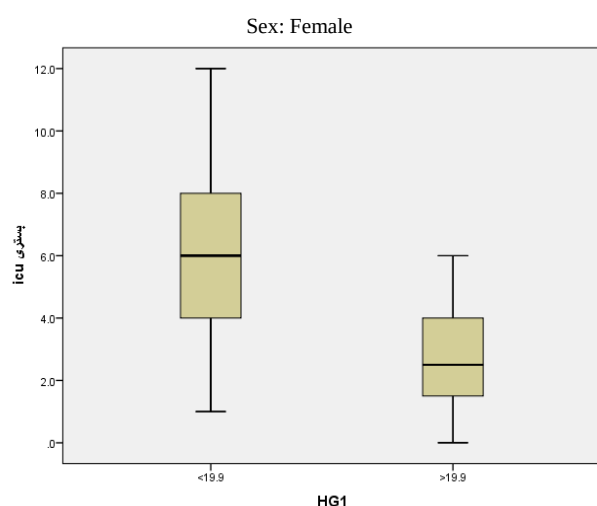


Figure 4. Comparison of ICU length of stay between female patients with handgrip strength (HGS) greater than 19.9 kg and those with HGS less than or equal to 19.9 kg.

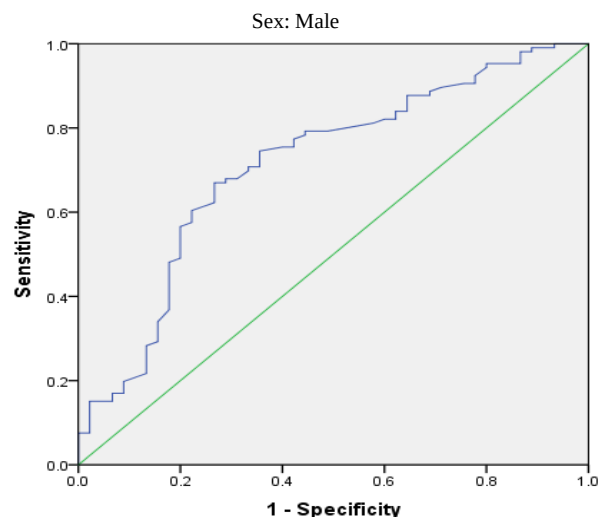


Figure 5. Receiver operating characteristic (ROC) curve analysis of handgrip strength (HGS) for predicting prolonged hospital length of stay in male patients. The findings suggest that preoperative HGS may be useful for identifying male patients at increased risk of prolonged postoperative hospitalization.

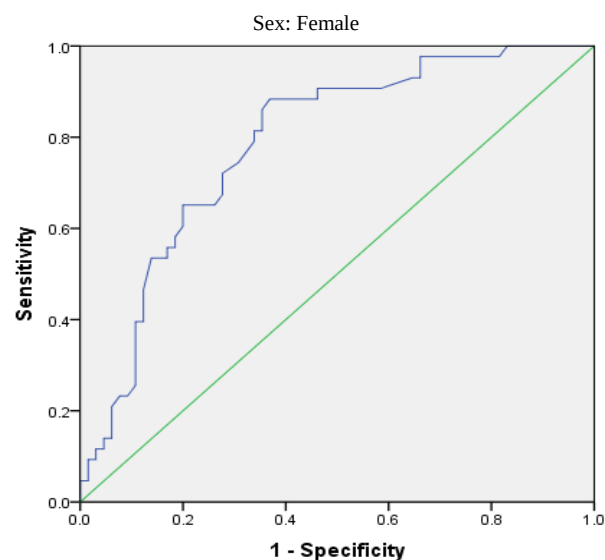


Figure 6. Receiver operating characteristic (ROC) curve analysis of handgrip strength (HGS) for predicting prolonged hospital length of stay in female patients.

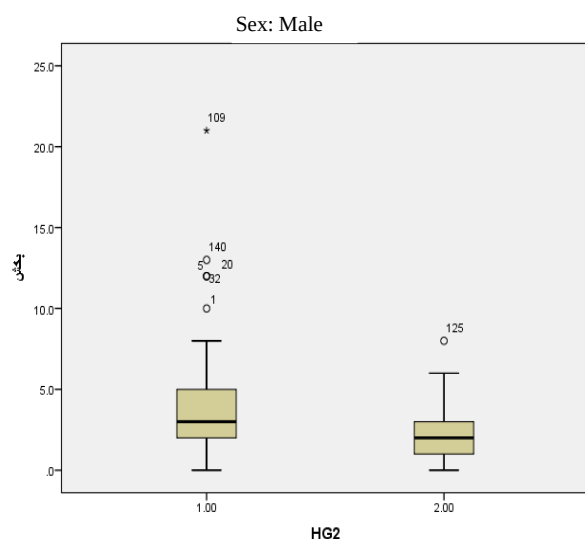


Figure 7. Comparison of hospital length of stay between male patients with handgrip strength (HGS) greater than 26.9 kg and those with HGS less than or equal to 26.9 kg.

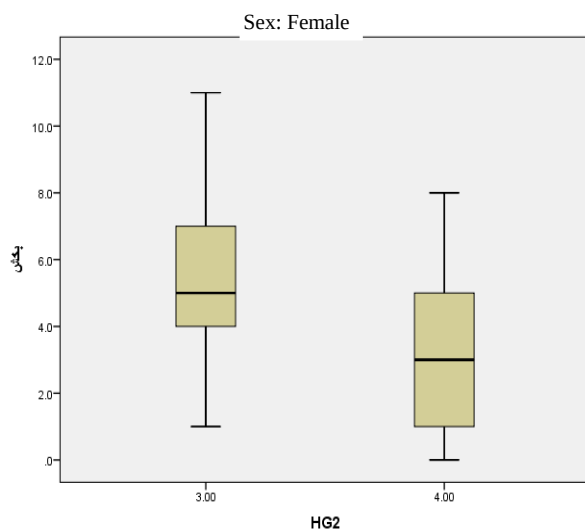


Figure 8. Comparison of hospital length of stay between female patients with handgrip strength (HGS) greater than 19.75 kg and those with HGS less than or equal to 19.75 kg.

Female patients with an HGS greater than 19.75 kg had a significantly shorter hospital length of stay compared to those with an HGS of 19.75 kg or less (approximately 3.0 vs. 6.5 days, $P < 0.001$; Cohen's $d = 2.5$). This substantial difference suggests that preoperative HGS may serve as a simple and practical indicator for identifying female patients at increased risk of prolonged postoperative hospitalization.

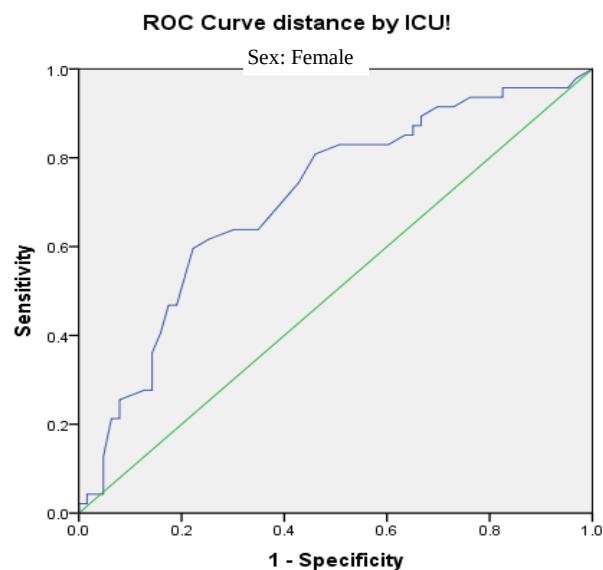


Figure 9. Receiver operating characteristic (ROC) curve analysis of the 6-minute walk distance (6MWD) for predicting prolonged ICU length of stay in male patients.

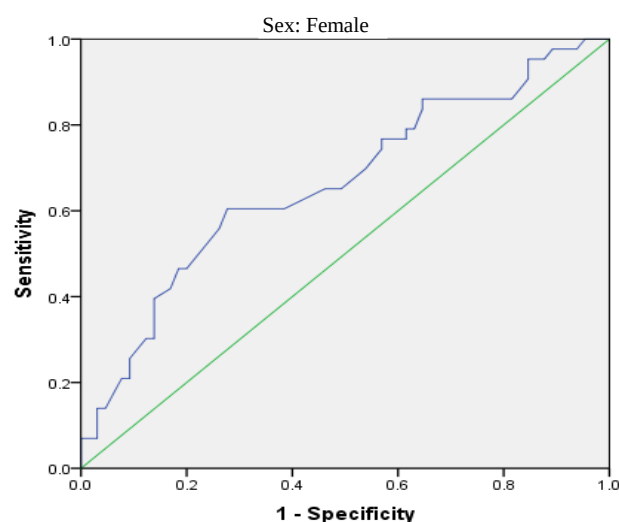


Figure 10. Receiver operating characteristic (ROC) curve analysis of the 6-minute walk distance (6MWD) for predicting prolonged ICU length of stay in female patients.

ROC curve analysis identified an optimal cutoff value of 402 meters for the 6MWD to predict prolonged ICU length of stay among female patients. Women with a preoperative 6MWD below 402 meters were more likely to experience prolonged ICU stay.

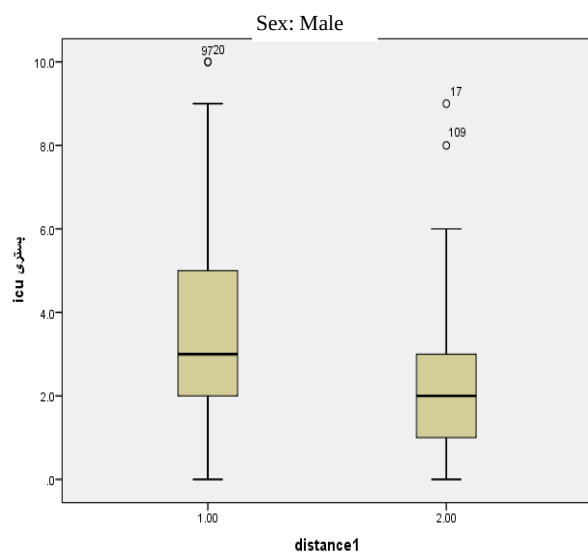


Figure 11. Comparison of ICU length of stay between male patients with a 6-minute walk distance (6MWD) greater than 414 meters and those with a 6MWD of 414 meters or less.

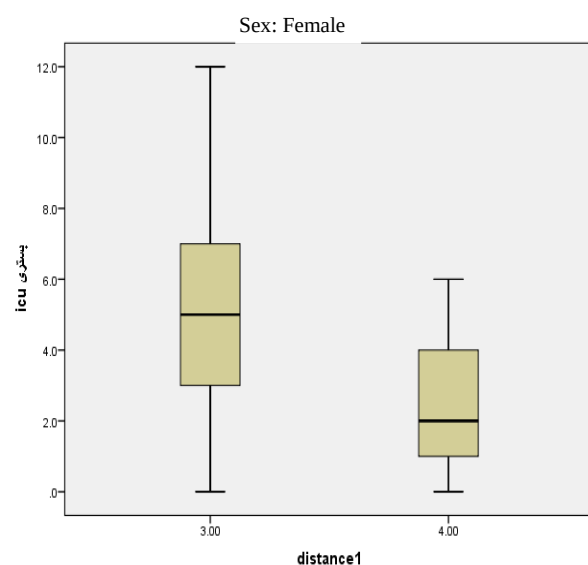


Figure 12. Comparison of ICU length of stay between female patients with a 6-minute walk distance (6MWD) greater than 402 meters and those with a 6MWD of 402 meters or less.

Among female patients, the mean ICU length of stay was significantly shorter in those with a preoperative 6MWD greater than 402 meters (2.52 ± 0.54 days) compared to those with a 6MWD of 402 meters or less (5.35 ± 0.70 days) ($P < 0.001$).

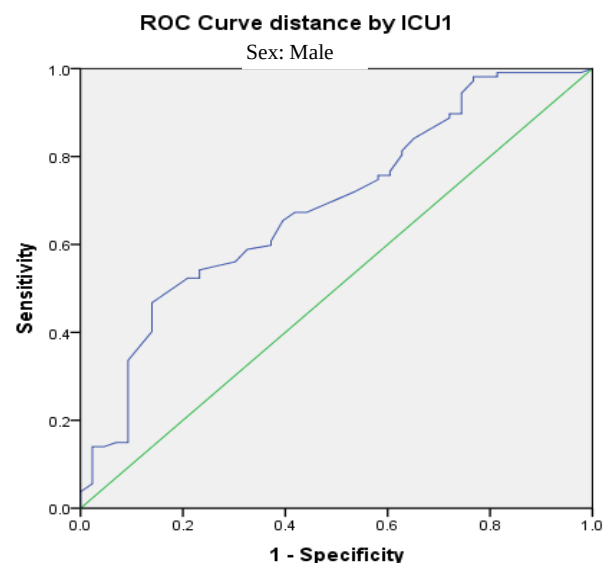


Figure 13. Receiver operating characteristic (ROC) curve analysis of the 6-minute walk distance (6MWD) for predicting prolonged hospital length of stay in male patients.

ROC curve analysis identified an optimal cutoff value of 428 meters for the 6MWD to predict prolonged hospital length of stay among male patients. However, as shown in Figure 15, no significant difference in hospital length of stay was observed between patients with preoperative 6MWD values above and below this cutoff.

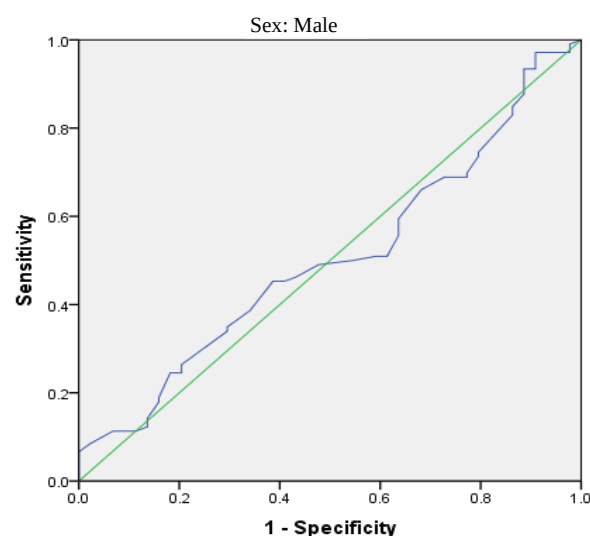


Figure 14. Receiver operating characteristic (ROC) curve analysis of the 6-minute walk distance (6MWD) for predicting prolonged hospital length of stay in female patients.

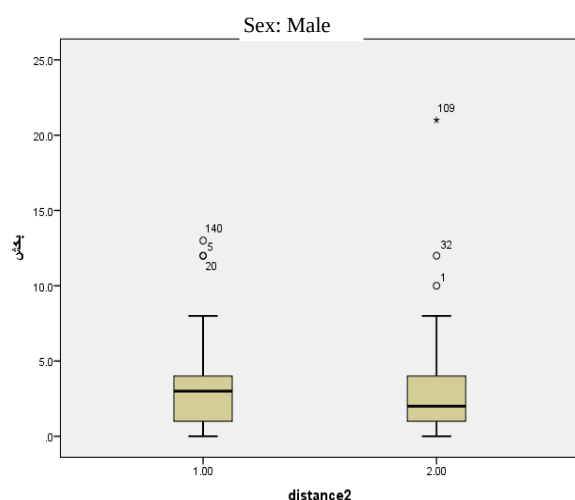


Figure 15. Comparison of hospital length of stay between male patients with a preoperative 6-minute walk distance (6MWD) greater than 428 meters and those with a 6MWD of 428 meters or less.

Among male patients, the mean hospital length of stay did not differ significantly between those with a preoperative 6MWD greater than 428 meters (2.89 ± 0.78 days) and those with a 6MWD of 428 meters or less (3.16 ± 0.54 days).

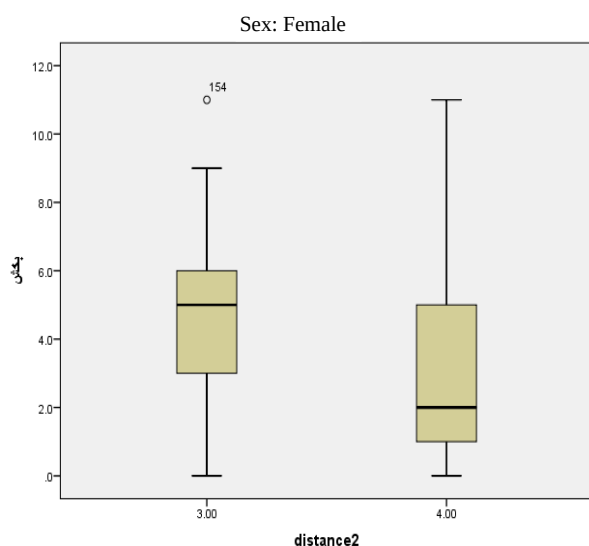


Figure 16. Comparison of hospital length of stay between female patients with a preoperative 6-minute walk distance (6MWD) greater than 390 meters and those with a 6MWD of 390 meters or less.

Association Between HGS and Hospital Length of Stay

ROC curve analysis identified optimal HGS cutoff values of 26.9 kg for male patients and 19.75 kg for female patients in predicting prolonged hospital length of stay (Figures 5 and 6). Comparison of group means demonstrated a significant association between preoperative HGS and hospital length of stay.

Among male patients, those with an HGS greater than 26.9 kg had a significantly shorter mean hospital length of stay compared to those with an HGS of 26.9 kg or less (1.80 ± 0.34 vs. 4.27 ± 0.68 days, $P < 0.001$; Cohen's $d = 3.2$). Similarly, female patients with an HGS greater than 19.75 kg experienced a significantly shorter hospital stay than those with an HGS of 19.75 kg or less (2.64 ± 0.44 vs. 5.96 ± 0.76 days, $P < 0.001$; Cohen's $d = 2.9$) (Table 3). These findings suggest that preoperative HGS may serve as a practical indicator for identifying patients at increased risk of prolonged postoperative hospitalization (Figures 7 and 8).

Association Between HGS, Extubation Success, and Mortality

Because only four patients required mechanical ventilation, the statistical analysis of the association between HGS and successful extubation was substantially underpowered. Although the observed p -value was 0.009, definitive conclusions could not be drawn because of the very small number of events. Similarly, only six in-hospital deaths occurred during the study period, which was insufficient to permit a reliable statistical analysis of the association between HGS and mortality.

Association Between 6MWD and Length of Stay Outcomes

To further evaluate the relationship between patients' functional capacity and postoperative clinical outcomes, ROC curve analysis was conducted using the 6MWD. The optimal cutoff values for predicting prolonged ICU length of stay were 414 meters for male patients and 402 meters for female patients (Figures 9 and 10).

Among male patients, the mean ICU length of stay was significantly shorter in those with a preoperative 6MWD greater than 414 meters

compared to those with a 6MWD of 414 meters or less (1.98 ± 0.44 vs. 3.31 ± 0.54 days, $P < 0.001$). Similarly, among female patients, the mean ICU length of stay was significantly shorter in those with a 6MWD greater than 402 m compared to those

with a 6MWD of 402 m or less (2.52 ± 0.54 vs. 5.35 ± 0.70 days, $P < 0.001$) (Table 4). These findings indicate that better preoperative functional capacity is significantly associated with a shorter ICU length of stay following surgery (Figures 11 and 12).

Table 2. Comparison of ICU Length of Stay According to Handgrip Strength (HGS) in Male and Female Patients

Sex	HGS Cutoff (kg)	n	ICU Length of Stay (days), Mean $\pm$ SD	P-value
Female	≤ 19.9	54	5.96 ± 0.76	<0.001
	> 19.9	55	2.64 ± 0.44	
Male	≤ 24.9	59	4.27 ± 0.68	<0.001
	> 24.9	92	1.80 ± 0.34	

Table 2. Comparison of ICU Length of Stay According to Handgrip Strength (HGS) in Male and Female Patients

Sex	Total (n)	HGS (kg)	Group (n)	ICU Length of Stay (days), Mean $\pm$ SD	P-value
Female	109	≤ 19.9	54	5.96 ± 0.76	<0.001
		> 19.9	55	2.64 ± 0.44	
Male	151	≤ 24.9	59	4.27 ± 0.68	<0.001
		> 24.9	92	1.80 ± 0.34	

Table 3. Comparison of Hospital Length of Stay According to Handgrip Strength (HGS) in Male and Female Patients

Sex	Total (n)	HGS (kg)	Group (n)	Hospital Length of Stay (days), Mean $\pm$ SD	P-value
Female	108	> 19.75	55	2.98 ± 0.48	<0.001
		≤ 19.75	53	5.56 ± 0.66	
Male	152	> 26.9	78	2.03 ± 0.33	<0.001
		≤ 26.9	74	4.98 ± 0.82	

Table 4. Comparison of ICU Length of Stay According to Preoperative 6-Minute Walk Distance (6MWD) in Male and Female Patients

Sex	Total (n)	6MWD (m)	Group (n)	ICU Length of Stay (days), Mean $\pm$ SD	P-value
Female	110	> 402	42	2.52 ± 0.54	<0.001
		≤ 402	68	5.35 ± 0.70	
Male	150	> 414	68	1.98 ± 0.44	<0.001
		≤ 414	82	3.31 ± 0.54	

Table 5. Comparison of Hospital Length of Stay According to Preoperative 6-Minute Walk Distance (6MWD) in Male and Female Patients

Sex	Total (n)	6MWD (m)	Group (n)	Hospital Length of Stay (days), Mean $\pm$ SD	P-value
Female	108	> 390	44	3.36 ± 0.81	0.003*
		≤ 390	64	4.85 ± 0.54	
Male	152	> 428	66	2.89 ± 0.78	0.563*
		≤ 428	86	3.16 ± 0.54	

* One P-value should be reported for each comparison between the two groups.

Association Between 6MWD and Hospital Length of Stay

Among male patients, the mean hospital length of stay did not differ significantly between those with a preoperative 6MWD greater than 428 m and those with a 6MWD of 428 m or less (2.89 ± 0.78 vs. 3.16 ± 0.54 days, $P = 0.575$). In contrast, among female patients, those with a 6MWD greater than 390 m had a significantly shorter hospital length of stay than those with a 6MWD of 390 m or less (3.36 ± 0.81 vs. 4.85 ± 0.54 days, $P = 0.003$; Cohen's $d = 1.2$) (Figures 15 and 16; Table 5). These findings suggest that better preoperative functional capacity, particularly among female patients, may be associated with a shorter postoperative hospital length of stay.

Discussion

The primary objective of the present study was to evaluate the association between preoperative HGS and 6MWD with postoperative length of stay outcomes. The main findings demonstrated significant correlations between both HGS and 6MWD and the length of stay in the ICU as well as the overall hospital stay. Patients with lower preoperative HGS and 6MWD experienced longer postoperative hospitalizations. Additionally, although only a small number of patients required mechanical ventilation, those with poorer preoperative functional performance tended to require a longer duration of ventilatory support.

Because only four patients required mechanical ventilation, the analysis of the association between HGS and successful liberation from mechanical ventilation was substantially underpowered. Consequently, no definitive conclusions can be drawn regarding this outcome. Nevertheless, the overall pattern of findings is consistent with the hypothesis that impaired preoperative functional status is associated with less favorable postoperative outcomes in patients undergoing surgery for intra-abdominal malignancies.

To our knowledge, this is the first study conducted in Iran to specifically investigate the relationship between preoperative HGS and successful liberation from mechanical ventilation in patients undergoing surgery for intra-abdominal malignancies.

The large effect sizes observed in this study (Cohen's d ranging from 2.1 to 3.2) indicate a strong distinction between patients with shorter and longer postoperative hospital stays based on preoperative HGS. However, these findings should be interpreted with caution, as deriving multiple cutoff values from the same dataset may increase the risk of overfitting. External validation is required before these thresholds can be recommended for routine clinical use.

The present findings are consistent with several previous international studies. Matsui et al. (2020) reported that non-cancer-related mortality was significantly higher among patients with low preoperative HGS than among those with preserved muscle strength. Furthermore, reduced preoperative HGS was identified as an adverse prognostic factor following gastrectomy for advanced gastric cancer and was associated with an increased risk of postoperative complications.⁴⁰ Similarly, studies involving patients with gastric and esophageal cancers have demonstrated that reduced preoperative muscle strength correlates with a higher incidence of postoperative complications.^{41,47,48}

In the study by Sato et al., 39.5% of patients with low HGS developed pneumonia within 30 days after surgery, compared to only 3.8% of patients with preserved HGS.⁴⁷ Furthermore, several studies have demonstrated that reduced HGS is associated with an increased risk of cardiovascular mortality.^{49,50} According to a systematic review by Rijk et al., HGS can serve as an indicator of mortality risk in the general population aged over 60 years.⁵¹ Additionally, Waki et al. reported that impaired muscle quality was associated with reduced survival after surgery in patients with gastric cancer.⁵²

From a clinical perspective, HGS is considered a practical measure for assessing preoperative muscle strength and functional status; however, it has certain limitations. HGS primarily evaluates upper-extremity strength and does not fully represent lower-extremity muscle function or overall mobility capacity, particularly in older adults or patients with neuromuscular disorders.⁵³ Nevertheless, Norman et al. demonstrated that HGS correlates strongly with other assessments of muscle function and may facilitate the evaluation of overall physical performance in patients with cancer.⁵⁴

In studies involving other types of abdominal surgery, including procedures for hepatocellular carcinoma and pancreatic cancer, sarcopenia and reduced muscle strength have also been reported as independent risk factors for postoperative complications.^{55,56}

From a physiological perspective, critically ill patients requiring mechanical ventilation and prolonged ICU admission are vulnerable to extensive muscle weakness, affecting not only the respiratory muscles but also the proximal limb muscles.⁵⁷ Therefore, HGS may represent a simple, rapid, and non-invasive tool for monitoring muscle status in ICU patients. It has also been shown to correlate significantly with the Medical Research Council (MRC) sum score, which is considered the standard assessment tool for peripheral muscle weakness.^{58,59}

The study by Cottureau et al. also reported an inverse association between HGS and the duration of mechanical ventilation, indicating that greater HGS was associated with shorter ventilator dependence. However, no direct association with successful extubation was demonstrated.⁶⁰ Similar findings were reported by Mohamed-Hussein et al. (2018) in patients with chronic obstructive pulmonary disease (COPD), where HGS was suggested as a useful marker for predicting extubation success and ICU length of stay.⁶¹

In the present study, in addition to HGS, the functional performance measure of the 6MWD was evaluated. The results demonstrated that, similar to HGS, lower preoperative 6MWD was inversely associated with ICU and hospital length of stay. These findings are consistent with those reported by Tomasz Marjanski et al. (2015), who demonstrated that the 6MWT can serve as a useful predictor of postoperative complications and prolonged hospitalization following lobectomy in patients with lung cancer.⁶²

Similarly, in the study by Dang et al. (2018) involving patients with cirrhosis, reduced performance on the 6MWT was identified as an indicator associated with increased mortality and postoperative complications following major surgical procedures. In that study, the mean survival time was reported as 25 months for patients with reduced 6MWT performance, compared to 69 months for those with preserved functional capacity.⁴⁵

Several limitations should be considered when interpreting these findings. First, the number of patients requiring mechanical ventilation was very small ($n = 4$), which limited the ability to perform a robust statistical analysis of successful liberation from mechanical ventilation. Second, this was a single-center study, which may restrict the generalizability of the findings. Future multicenter studies with larger sample sizes are warranted to validate these results.

Another limitation was the derivation of multiple cutoff values from the same dataset without external validation, which may increase the risk of overfitting. Future studies should include external validation cohorts and consider survival analysis to evaluate long-term outcomes.

Additionally, sarcopenia was not directly assessed using imaging-based methods such as computed tomography (CT) or dual-energy X-ray absorptiometry (DEXA). Finally, the sample size was calculated based on mortality rather than the primary outcome of length of stay, which may have affected the statistical power of certain analyses.

Conclusion

The findings of this study demonstrated significant associations between preoperative HGS and 6MWD with postoperative outcomes, including the length of stay in the ICU and hospital, in patients undergoing surgery for intra-abdominal malignancies.

These results suggest that preoperative HGS and 6MWD may serve as valuable indicators of unfavorable postoperative outcomes. They can help identify patients at higher risk and improve perioperative clinical decision-making. Given their simplicity, low cost, and noninvasive nature, HGS and 6MWD are practical screening tools for assessing the risk of prolonged hospitalization following surgery for intra-abdominal cancers.

Further multicenter studies with larger sample sizes and external validation of the proposed cutoff values are required to confirm the clinical applicability of these measures. Future investigations should also evaluate these functional parameters in other patient populations, including individuals with cardiovascular, pulmonary, and neuromuscular

disorders, to determine their broader predictive utility and generalizability.

Moreover, interventional studies focusing on improving preoperative muscle strength and physical fitness, such as structured prehabilitation programs, may help reduce

postoperative complications and improve patients' quality of life.

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References

1. Sonnenschein C, Soto AM. Theories of carcinogenesis: an emerging perspective. *Semi Cancer Biol.* 2008; 18(5): 372-7.
2. Vogelstein B, Kinzler KW. Cancer genes and the pathways they control. *Nat Med.* 2004; 10(8): 789-99.
3. Hidalgo M, Cascinu S, Kleeff J, Labianca R, Lohr JM, Neoptolemos J, Real FX, et al. Addressing the challenges of pancreatic cancer: future directions for improving outcomes. *Pancreatology.* 2015; 15(1): 8–18. doi: 10.1016/j.pan.2014.10.001.
4. Ferlay J, Soerjomataram I, Dikshit R, Eser S, Mathers C, Rebelo M, Parkin DM, Forman D, Bray F. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. *Int J Cancer.* 2015;136:359–86.
5. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin.* 2018; 68(6): 394–424. doi: 10.3322/caac.21492.
6. Ferlay J EM, Lam F, Colombet M, Mery L, Pineros M, Znaor A, Soerjomataram I, Global cancer observatory: cancer today. Lyon, France: International Agency for Research on Cancer; Available from: <https://gco.iarc.fr/today>, Accessed 05 October 2018.
7. Brunicaudi FC, Andersen DK, Billiar TR, Dunn DL, Hunter JG, Schwartz Principle of surgery, new york: MC GrowHills;2005
8. Xiang-FU Zhong, Chang ningHuang, Hui-Shanlu. Surgical treatment and prognosis of gastric cancer in 2613 patients. *World J gastroenterol* 2004; 10(23):3405-8
9. Malekzadeh R, Sotodeh M, Darakhshan MH. Prevalance of gastric adenocarcinoma lesions in Ardebil, a high incidence province for gastric adenocarcinoma in the north west of Iran. *J clinic pathology* 2004; 57: 37-42.
10. Onote-ocana Luis F, Gallorderinca D, Aiello-crocifoglio V. The role of prethraputic laparoscopy in the selection of treatment for patient with gastric carcinoma: a proposal for a laparoscopic staging system. *Annals of surgical oncology.* 2001; 8(8): 624-631.
11. Fazel R, Krumholz HM, Wang R, et al. Exposure to Low-dose ionizing radiation from medical imaging procedures. *N Engl J Med.* 2009; 361(9):849-57.
12. William WN Jr, Heymach JV, Kim ES, et al. Molecular targets for cancer chemoprevention. *Nat Rev Drug Discov.* 2009; 8(3): 213-25.
13. Jeong SH, Ahn HS, Yoo MW, Cho JJ, Lee HJ, Kim HH, et al. Increased morbidity rates in patients with heart disease or chronic liver disease following radical gastric surgery. *Journal of surgical oncology.* 2010; 101(3): 200-4.
14. Sugisawa N, Tokunaga M, Tanizawa Y, Bando E, Kawamura T, Terashima M. Intra-abdominal infectious complications following gastrectomy in patients with excessive visceral fat. *Gastric Cancer.* 2012; 15(2):206-12.
15. Mitsuro Kanda. Preoperative predictors of postoperative complications after gastric cancer resection. *Surgery Today* (2020) 50:3–11
16. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *New England Journal of Medicine.* 2009; 360(14):1418-28.
17. Kunisaki C, Miyata H, Konno H, Saze Z, Hirahara N, Kikuchi H, et al. Modeling preoperative risk factors for potentially lethal morbidities using a nationwide Japanese web-based database of patients undergoing distal gastrectomy for gastric cancer. *Gastric Cancer.* 2017; 20:496–507.
18. Asgari MR, Soleimani M. Comprehensive Book Intensive Nursing Care in ICU, CCU and Dialysis Wards. 4th ed. Tehran: Boshra; 2016. p. 249, 58-75, 313, 35-36
19. Burns MS. AACN Essentials of critical Care Nursing. 1th ed. Tehran: JameeNegar; 2016. p. 107-13, 23-36.
20. Esen S, Leblebicioglu H. Prevalence of nosocomial infections at intensive care units in Turkey: a multicentre 1-day point prevalence study. *Scand J of Infec Dis.* 2004;36(2):144-8.
21. Radhakrishnan M, Indranil G, Dash H. Evaluation of an Indigenous Ventilator for Weaning in Intensive Care Unit. *J Anaesthesia pharmacology* 2007; 23(3): 297-301.
22. Turan Inal M, Memiş D, Yildirim İ. Comparison of extubation times between protocolized versus automated weaning systems after major surgery in the intensive care unit. *SIGNA VITAE.* 2012; 7(1):23-7.
23. Ely EW, Meade MO, Haponik EF, Kollef MH, Cook DJ, Guyatt GH, et al. Mechanical Ventilator Weaning Protocols Driven by Non physician Health-Care Professionals Evidence-Based Clinical Practice Guidelines. *CHEST.* 2001; 120(6 suppl):454S-63S.
24. McLean SE, Jensen LA, Schroeder DG, Gibney NR, Skjoldt NM. Improving adherence to a mechanical ventilation weaning protocol for critically ill adults: outcomes after an implementation program. *Am J Crit Care.* 2006; 15(3): 299-309.
25. Fu L, Zhang Y, Shao B, Liu X, Yuan B, Wang Z, et al. Perioperative poor grip strength recovery is associated with 30-day complication rate after cardiac surgery discharge in middle-aged and older adults—a prospective observational study. *BMC cardiovascular disorders.* 2019; 19(1):1-9.
26. Porto JM, Nakaishi APM, Cangussu-Oliveira LM, Júnior RCF, Spilla SB, de Abreu DCC. Relationship between grip strength and global muscle strength in

- community-dwelling older people. *Archives of Gerontology and Geriatrics*. 2019;82: 273-8.
27. Ueda P, Woodward M, Lu Y, et al. Laboratory-based and office-based risk scores and charts to predict 10-year risk of cardiovascular disease in 182 countries: a pooled analysis of prospective cohorts and health surveys. *Lancet Diabetes Endocrinol* 2017;5: 196-213.
 28. Guo W, Bradbury KE, Reeves GK, Key TJ. Physical activity in relation to body size and composition in women in UK Biobank. *Ann Epidemiol* 2015; 25: 406-413.e6. doi:10.1016/j.annepidem.2015.01.015.
 29. Palmela C, Velho S, Agostinho L et al. Body Composition as a prognostic factor of neoadjuvant chemotherapy toxicity and outcome in patients with locally advanced gastric cancer. *J Gastric Cancer* 2017; 17: 74–87.
 30. Rangel E L, Rios-Diaz A J, Uyeda J W et al. Sarcopenia increases risk of long-term mortality in elderly patients undergoing emergency abdominal surgery. *J Trauma Acute Care Surg* 2017; 83: 1179–86.
 31. Yu J, Hu J, Huang C, Ying M, Peng X, Wei H, et al. The impact of age and comorbidity on postoperative complications in patients with advanced gastric cancer after laparoscopic D2 gastrectomy: results from the Chinese Laparoscopic Gastrointestinal Surgery Study (CLASS) group. *Eur J Surg Oncol*. 2013;39:1144–9.
 32. Antoun S, Lanoy E, Iacovelli R, Albiges-Sauvin L, Lorient Y, Merad-Taoufik M, et al. Skeletal muscle density predicts prognosis in patients with metastatic renal cell carcinoma treated with targeted therapies. *Cancer*. 2013;119(18):3377–84.
 33. Kaido T, Ogawa K, Fujimoto Y, Ogura Y, Hata K, Ito T, et al. Impact of sarcopenia on survival in patients undergoing living donor liver transplantation. *Am J Transplant*. 2013; 13: 1549–56.
 34. Melissa M. Eden PT, DPT, James Tompkins PT, DPT & Joseph L. Verheijde PT, Reliability and a correlational analysis of the 6MWT, ten-meter walk test, thirty second sit to stand, and the linear analog scale of function in patients with head and neck cancer, *Physiotherapy Theory and Practice* An International Journal of Physical Therapy, ISSN: 0959-3985 (Print) 1532-5040 (Online) Journal homepage: <http://www.tandfonline.com/loi/iptp20>.
 35. Goldstein DP, Ringash J, Bissada E, Jaquet Y, Irish J, Chepeha D, Davis AM 2014 Scoping review of the literature on shoulder impairments and disability after neck dissection. *Head and Neck* 36: 299–308.
 36. Feliciano EMC, Kroenke CH, Meyerhardt JA, et al. Association of Systemic Inflammation and Sarcopenia with Survival in Nonmetastatic Colorectal Cancer: Results from the C SCANS Study. *JAMA Oncol*. 2017; 3(12):e172319.
 37. Rangel EL, Rios-Diaz AJ, Uyeda JW, et al. Sarcopenia increases risk of long-term mortality in elderly patients undergoing emergency abdominal surgery. *J Trauma Acute Care Surg*. 2017;83(6): 1179–86.
 38. Aoyama T, Sato T, Segami K, et al. Risk factors for the loss of lean body mass after gastrectomy for gastric cancer. *Ann Surg Oncol*. 2016;23(6): 1963–70.
 39. Ashabi A, Hejazi S, Mofidi-Nejad M, Ramezani A, Nazari M. Evaluation of nutritional status of hemodialysis patients by hand grip strength. *Koomesh*. 2022 Aug 10; 24(4):496-503.
 40. Matsui R, Inaki N, Tsuji T. The impact of the preoperative hand grip strength on the long-term outcomes after gastrectomy for advanced gastric cancer. *Surgery Today*. 2021 Jul;51(7):1179-87.
 41. Sato T, Aoyama T, Hayashi T, Segami K, Kawabe T, Fujikawa H, et al. Impact of preoperative hand grip strength on morbidity following gastric cancer surgery. *Gastric Cancer*. 2016;19(3):1008–15.
 42. A Celis-Morales C, Welsh P, M Lyall D, Steell L, Petermann F et al, Associations of grip strength with cardiovascular, respiratory, and cancer outcomes and all cause mortality: prospective cohort, study of half a million UK Biobank participants, *BMJ*: first published as 10.1136/bmj.k1651 on 8 May 2018.
 43. Boshier P. R, Heneghan R, Markar S. R, Baracos V. E, Low D. E, Assessment of Body Composition and sarcopenia in patients with esophageal cancer: a systematic review and meta-analysis Published by Oxford University Press on behalf of International Society for Diseases of the Esophagus *Diseases of the Esophagus*(2018)31, 1–11.
 44. Sivesh K. Kamarajah, James Bundred & Benjamin H. L. Tan, Body Composition assessment and sarcopenia in patients with gastric cancer: a systematic review and meta-analysis, The International Gastric Cancer Association and The Japanese Gastric Cancer Association, *Gastric Cancer* (2019) 22: 10–22.
 45. Dang T, Ebadi M, Montano-Loza A, Tandon P. A six-minute walk test and sarcopenia in predicting mortality in patients with cirrhosis. *Journal of the Canadian Association of Gastroenterology*. 2018; 1(Suppl-2): 269-79
 46. Kohl LdM, Signori LU, Ribeiro RA, Silva AMV, Moreira PR, Dipp T, et al. Prognostic value of the six-minute walk test in end-stage renal disease life expectancy: a prospective cohort study. *Clinics*. 2012; 67(67): 581-6
 47. Sato S, Nagai E, Taki Y, Watanabe M, Watanabe Y, Nakano K, et al. Hand grip strength as a predictor of postoperative complications in esophageal cancer patients undergoing esophagectomy. *Esophagus*. 2018; 15(1): 10–8.
 48. Ma BW, Chen XY, Fan SD, Zhang FM, Huang DD, Li B, et al. Impact of sarcopenia on clinical outcomes after radical gastrectomy for patients without nutritional risk. *Nutrition*. 2019; 61: 61–6.

49. Chainani V, Shaharyar S, Dave K, Choksi V, Ravindranathan S, Hanno R, et al. Objective measures of the frailty syndrome (hand grip strength and gait speed) and cardiovascular mortality: a systematic review. *Int J Cardiol.* 2016;215:487–93.
50. Afilalo J, Karunanathan S, Eisenberg MJ, Alexander KP, Bergman H. Role of frailty in patients with cardiovascular disease. *Am J Cardiol.* 2009;103(11):1616–21.
51. Rijk JM, Roos PR, Deckx L, van den Akker M, Buntinx F. Prognostic value of handgrip strength in people aged 60 years and older: a systematic review and meta-analysis. *Geriatr Gerontol Int.* 2016;16(1):5–20.
52. Waki Y, Irino T, Makuuchi R, Notsu A, Kamiya S, Tanizawa Y, et al. Impact of preoperative skeletal muscle quality measurement on long-term survival after curative gastrectomy for locally advanced gastric cancer. *World J Surg.* 2019;43(12):3083–93.
53. Prado CM, Lieffers JR, McCargar LJ, Reiman T, Sawyer MB, Martin L, et al. Prevalence and clinical implications of sarcopenic obesity in patients with solid tumours of the respiratory and gastrointestinal tracts: a population-based study. *Lancet Oncol.* 2008; 9: 629–35.
54. Norman K, Stobaus N, Smoliner C, Zocher D, Scheufele R, Valentini L, et al. Determinants of hand grip strength, knee extension strength and functional status in cancer patients. *Clin Nutr.* 2010; 29: 586–91.
55. Valero V 3rd, Amini N, Spolverato G, Weiss MJ, Hirose K, Dagher NN, et al. Sarcopenia adversely impacts postoperative complications following resection or transplantation in patients with primary liver tumors. *J Gastrointest Surg.* 2015; 19: 272–81.
56. Amini N, Spolverato G, Gupta R, Margonis GA, Kim Y, Wagner D, et al. Impact total psoas volume on short- and long-term outcomes in patients undergoing curative resection for pancreatic adenocarcinoma: a new tool to assess sarcopenia. *J Gastrointest Surg.* 2015;19:1593–602.
57. Hermans G, Van den Berghe G. Clinical review: intensive care unit acquired weakness. *Crit Care.* 2015; 19:274.
58. Stevens RD, Marshall SA, Cornblath DR, Hoke A, Needham DM, de Jonghe B, et al. A framework for diagnosing and classifying intensive care unit-acquired weakness. *Crit Care Med* 2009; 37(10 Suppl): S299–S308.
59. De Jonghe B, Bastuji-Garin S, Sharshar T, Outin H, Brochard L. Does ICU acquired paresis lengthen weaning from mechanical ventilation. *Intensive Care Med* 2004; 30(6):1117–1121.
60. Cottreau G, Dres M, Avenel A, Fichet J, Jacobs FM, Prat D, et al. Handgrip Strength Predicts Difficult Weaning But Not Extubation Failure in Mechanically Ventilated Subjects. *Respiratory care.* 2015.
61. Mohamed-Hussein AAR, Makhoul HA, Selim ZI, Gamaleldin Saleh W. Association between hand grip strength with weaning and intensive care outcomes in COPD patients: a pilot study. *Clin Respir J.* 2018; 12: 2475–2479.
62. Marjanski T, Wnuk D, Bosakowski D, Szmuda T, Sawicka W, Rzyman W. Patients who do not reach a distance of 500 m during the 6-min walk test have an increased risk of postoperative complications and prolonged hospital stay after lobectomy. *Eur J Cardiothorac Surg* 2015; 47: e213–e9.