ARCHIVES OF THE TURKISH SOCIETY OF CARDIOLOGY

Official journal of the TURKISH SOCIETY OF CARDIOLOGY

Associations Between Upper Extremity Function, Activities of Daily Living, and Functional Capacity in Patients with Heart Failure with Reduced Ejection Fraction

Düşük Ejeksiyon Fraksiyonlu Kalp Yetersizliği Hastalarında Üst Ekstremite Fonksiyonu, Günlük Yaşam Aktiviteleri ve Fonksiyonel Kapasite Arasındaki İlişkiler

ABSTRACT

Objective: Limited information is available regarding the associations between upper extremity function, activities of daily living (ADLs), and functional capacity in patients with heart failure with reduced ejection fraction (HFrEF). This study aimed to investigate the associations between upper extremity function, ADLs, and functional capacity in patients with HFrEF.

Methods: This cross-sectional study included 31 patients with HFrEF. Demographic, anthropometric, and clinical data were recorded. Upper extremity function and ADLs were evaluated using the 6-Minute Pegboard and Ring Test (6PBRT) and the Glittre Activities of Daily Living Test (TGlittre), respectively. The 6-Minute Walk Test (6MWT) was administered to measure functional capacity. Heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), peripheral oxygen saturation (SpO_2), dyspnea, and fatigue were assessed at the beginning and end of each test.

Results: The 6PBRT was significantly correlated with TGlittre (*rho* = -0.718, $P < 0.001$) and 6-minute walk distance (6MWD) ($r = 0.546$, $P = 0.001$). A significant correlation was also found between TGlittre and 6MWD (*rho* = -0.810, $P < 0.001$). Changes in HR, SBP, and dyspnea were significantly different across the 6PBRT, TGlittre, and 6MWT ($P < 0.05$).

Conclusion: This study indicates that upper extremity function is associated with ADLs and functional capacity in patients with HFrEF. The 6PBRT requires lower cardiopulmonary demand than TGlittre and 6MWT in this patient population.

Keywords: Activities of daily living, functional capacity, heart failure, upper extremity function

ÖZET

Amaç: Düşük ejeksiyon fraksiyonlu kalp yetersizliği (DEFKY) olan hastalarda üst ekstremite fonksiyonu, günlük yaşam aktiviteleri ve fonksiyonel kapasite arasındaki ilişkiler konusunda sınırlı bilgi vardır. Bu çalışmanın amacı DEFKY'li hastalarda üst ekstremite fonksiyonu, günlük yaşam aktiviteleri (GYA) ve fonksiyonel kapasite arasındaki ilişkileri araştırmaktı.

Yöntem: Bu kesitsel çalışmaya toplam 31 DEFKY'li hasta katıldı. Demografik, antropometrik ve klinik veriler kaydedildi. Üst ekstremite fonksiyonu ve GYA sırasıyla 6 Dakika Pegboard ve Ring Testi (6PBRT) ve Glittre ADL Testi (TGlittre) ile değerlendirildi. 6 Dakika Yürüme Testi (6DYT) fonksiyonel kapasiteyi ölçmek için kullanıldı. Her testin başında ve sonunda kalp hızı (KH), sistolik kan basıncı (SKB), diyastolik kan basıncı (DKB), periferik oksijen satürasyonu (SpO_2), dispne ve yorgunluk değerlendirildi.

Bulgular: 6PBRT, TGlittre (*rho* = -0,718, $P < 0,001$) ve 6 dakika yürüme mesafesi (6DYM) ($r = 0,546$, $P = 0,001$) ile anlamlı düzeyde korele idi. TGlittre ile 6DYM arasında anlamlı bir korelasyon bulundu (*rho* = -0,810, $P < 0,001$). KH, SKB ve dispnedeki değişiklikler 6PBRT, TGlittre ve 6DYT arasında anlamlı derecede farklıydı ($P < 0,05$).

Sonuç: Çalışmamız DEFKY'li hastalarda üst ekstremite fonksiyonunun günlük yaşam aktiviteleri ve fonksiyonel kapasite ile ilişkili olduğunu göstermektedir. Bu hasta popülasyonunda 6PBRT, TGlittre ve 6DYT'ye göre daha düşük kardiyopulmoner talep gerektirir.

Anahtar Kelimeler: Günlük yaşam aktiviteleri, fonksiyonel kapasite, kalp yetersizliği, üst ekstremite fonksiyonu

ORIGINAL ARTICLE
KLİNİK ÇALIŞMA

Aylin Tanrıverdi Eyolcu[1]
Buse Özcan Kahraman[2]
Ebru Özpelit[3]
Serap Acar[2]
Bihter Şentürk[3]
İsmail Özsoy[4]
Bahri Akdeniz[3]
Mehmet Birhan Yılmaz[3]
Sema Savcı[5]

[1]Department of Physiotherapy and Rehabilitation, Çankırı Karatekin University, Faculty of Health Sciences, Çankırı, Türkiye
[2]Dokuz Eylül University, Faculty of Physical Therapy and Rehabilitation, Izmir, Türkiye
[3]Department of Cardiology, Dokuz Eylül University, Faculty of Medicine, Izmir, Türkiye
[4]Department of Physical Therapy and Rehabilitation, Selcuk University, Faculty of Health Sciences, Konya, Türkiye
[5]Department of Physiotherapy and Rehabilitation, Acıbadem Mehmet Ali Aydınlar University,Faculty of Health Sciences, İstanbul, Türkiye

Corresponding author:
Aylin Tanrıverdi Eyolcu
✉ aylintanriverdi@karatekin.edu.tr

Received: June 07, 2024
Accepted: October 31, 2024

Cite this article as: Tanrıverdi Eyolcu A, Özcan Kahraman B, Özpelit E, et al. Associations Between Upper Extremity Function, Activities of Daily Living, and Functional Capacity in Patients with Heart Failure with Reduced Ejection Fraction. *Turk Kardiyol Dern Ars.* 2025;53(1):22-28.

DOI:10.5543/tkda.2024.79916

Heart failure (HF) is a significant public health problem, contributing to high mortality rates.[1] Globally, an estimated 64 million individuals are affected by HF, with its prevalence increasing in many middle- and low-income countries.[1,2] Despite advancements in medical treatment, the number of years lived with disability due to HF has risen, especially in middle- and low-income countries.[1]

HF can impair skeletal muscle metabolic activity in both the upper and lower extremities.[3] Additionally, muscle mass in the upper and lower extremities has a prognostic impact on mortality in HF patients.[4] However, upper extremity function has often been overlooked in this population. Upper extremity function can be assessed using different methods, one of which is the 6-Minute Pegboard and Ring Test (6PBRT), which reflects upper-extremity activities of daily living (ADLs).[5,6] Upper extremity function as measured by the 6PBRT has been shown to correlate with functional capacity and ADLs in patients with pulmonary hypertension and chronic obstructive pulmonary disease (COPD).[7,8]

It is likely that a strong association exists between low exercise tolerance and functional disability, as assessed by submaximal and functional tests, in patients with heart failure with reduced ejection fraction (HFrEF). However, limited information is available on the associations between upper extremity function, ADLs, and functional capacity in patients with HFrEF. Understanding these associations would enable healthcare professionals to develop more personalized and targeted disease management strategies. Therefore, this study aimed to investigate the associations between upper extremity function, ADLs, and functional capacity in patients with HFrEF. A secondary aim was to compare the physiological responses to the 6PBRT, Glittre Activities of Daily Living Test (TGlittre), and 6-Minute Walk Test (6MWT) to assess the extent of physiological capacity required to perform each test.

Materials and Methods

This prospective, cross-sectional study was conducted in the Department of Cardiology at Dokuz Eylül University Hospital from April 2023 to December 2023. Patients diagnosed with HFrEF according to international guidelines were enrolled in this study.[9,10] Additional inclusion criteria were being over 18 years of age, clinically stable as classified by New York Heart Association (NYHA) functional class II–III, and willing to participate. Exclusion criteria included a history of acute coronary syndrome within the past six months, any orthopedic, neurological, or cognitive condition that could limit test performance, or severe pulmonary disease.

This study received ethical approval from the Dokuz Eylül University Non-Invasive Research Ethical Committee (Approval Number: 2023/03-05, Date: 18.01.2023), and all participants provided written informed consent. The study was conducted in compliance with the Declaration of Helsinki.

Assessments

Functional Class

Functional class was assessed using the NYHA scale, a valid measure for patients with cardiac disease.[11] The NYHA functional classification system categorizes patients into classes 1 through 4 based on the impact of cardiac symptoms on daily activities. Higher NYHA functional classes indicate greater disease severity.

Dyspnea Perception

Dyspnea perception was assessed using the modified Medical Research Council (mMRC) scale. The mMRC scale consists of five items, where a score 0 indicates dyspnea only with strenuous exercise, and a score 4 indicates dyspnea even during dressing or undressing.

Pulmonary Function

Pulmonary function was assessed using a spirometer (Minispir® MIR s.r.l., Rome, Italy), following recommended guidelines.[12] Forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio were recorded as percentages.

Functional Capacity

Functional capacity was measured using the 6-Minute Walk Test.[13] The test was conducted following standard guidelines.[14] Participants were instructed to walk a 20-meter straight hallway as quickly as possible over six minutes. After the test began, participants were informed of the remaining time each minute, and standardized encouragement was provided. The total distance covered during the test was recorded as the 6-minute walk distance (6MWD). The predicted percentage of the 6MWD ($6MWD\%_{predicted}$) was calculated using reference equations.[15]

Activities of Daily Living (ADLs)

ADLs were assessed with the Glittre Activities of Daily Living Test (TGlittre), an applicable and reproducible tool for patients with HF.[16,17] The test was conducted following the original protocol for TGlittre in patients with COPD.[18] The TGlittre consists of a 10-meter circuit that includes a two-step staircase with each step measuring 27 cm deep and 17 cm high, along with two shelves positioned at shoulder and waist height for each participant. Participants wore a backpack weighing 5.0 kg for men and 2.5 kg for women throughout the TGlittre. The TGlittre began with participants rising from a seated position, followed by walking, ascending and descending the two steps, and walking again to reach the shelves. Three 1 kg weights placed on the upper shelf were moved one at a time to the lower shelf, then to the floor, back to the lower shelf, and finally returned to the upper shelf. Participants then turned around, walked back across the stairs to their chairs, sat down, and promptly began the next lap by

ABBREVIATIONS

6MWT	6-Minute Walk Test
6PBRT	6-Minute Pegboard and Ring Test
ADLs	Activities of daily living
COPD	Chronic obstructive pulmonary disease
DBP	Diastolic blood pressure
FEV_1	Forced expiratory volume in one second
FVC	Forced vital capacity
HFrEF	Heart failure with reduced ejection fraction
HR	Heart rate
mMRC	Modified Medical Research Council
NYHA	New York Heart Association
SBP	Systolic blood pressure
SpO_2	Peripheral oxygen saturation
TGlittre	Glittre Activities of Daily Living Test

standing up again. Participants were instructed to complete five rounds as quickly as possible, and the total duration of the TGlittre was recorded. The percentage of the predicted TGlittre duration (TGlittre%$_{predicted}$) was calculated using the reference equation.[19]

Upper Extremity Function

Upper extremity function was assessed using the 6PBRT. The test was conducted following the protocol described in the initial study on the 6PBRT in patients with COPD.[20] A pegboard was positioned in front of each participant within arm's reach while they sat upright in a chair. The pegboard included two pegs at shoulder level and two additional pegs positioned 20 cm above shoulder level. Ten lightweight wooden rings were hung individually on each of the bottom two pegs. Participants were instructed to move one ring from each bottom peg to the top peg, using both hands simultaneously. Once all rings were transferred to the top pegs, participants moved the rings back to the bottom pegs. This task was repeated as quickly as possible for six minutes, with standardized verbal encouragement provided each minute. The total number of rings moved during the 6PBRT was recorded, and the percentage of the predicted 6PBRT value (6PBRT%$_{predicted}$) was calculated using the reference equation.[21]

Procedure

The study procedure consisted of a single visit. First, demographic and anthropometric data were collected, and left ventricular ejection fraction and medication information were retrieved from the latest patient records. Next, functional class, dyspnea perception, and pulmonary function were assessed. Finally, the 6PBRT, TGlittre, and 6MWT were conducted in random order, determined by a computerized random number generator (www.random.org). Heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), peripheral oxygen saturation (SpO_2), dyspnea, and fatigue were measured at the beginning and end of each test. The next test was initiated only after these physiological parameters returned to their baseline levels evaluated at the start of the test.

Statistical Analysis

The study sample size was calculated using G*Power software (version 3.1.9.2,Düsseldorf, Germany), based on a previous study investigating the association between 6MWD and TGlitttre in patients with HF.[22] Considering an effect size of 0.484, a power of 0.80, and an alpha error probability of 0.05, the minimum required sample size was determined to be 28 participants.

Statistical analyses were conducted using IBM SPSS software (version 26, IBM, Armonk, NY, USA). The normality of the data distribution was assessed with the Shapiro-Wilk test and histograms. Descriptive and categorical data were expressed as mean ± standard deviation (SD), median (interquartile range), or number (percentage), as appropriate. The correlation between the 6PBRT and 6MWD was analyzed using Pearson's product-moment correlation, as parametric conditions were met. Correlations among other variables were analyzed using Spearman's rank-order correlation, as nonparametric conditions were met. Correlation strength was classified as weak (0.20-0.39), moderate (0.40-0.59), strong (0.60-0.79), or very strong (0.80-1.0).[23] Comparisons of physiological values obtained before and after each test were analyzed using the Wilcoxon test or paired sample t-test, as appropriate. Differences among physiological responses to the tests were analyzed using repeated measures Analysis of Variance (ANOVA) or the Friedman test, as appropriate. Post-hoc analyses were conducted with Bonferroni correction. Statistical significance was set at $P < 0.05$.

Results

A total of 31 patients with HFrEF participated in this study. Table 1 presents the demographic, anthropometric, and clinical characteristics of the participants. The mean age was 62.13 ± 9.38 years. Most participants were men (87.1%), were classified as overweight (48.4%), and fell into NYHA functional class II

Table 1. Demographic and Clinical Features

Variables	Total Participants (n = 31)
Age, years	62.13 ± 9.38
Gender, n (%)	
Women	4 (12.9)
Men	27 (87.1)
Body mass index, kg/m^2	27.97 (24.51-30.40)
LVEF, %	30.00 (20.00-35.00)
NYHA functional class, n (%)	
II	18 (58.1)
III	13 (41.9)
Medication, n (%)	
Beta-blockers	27 (87.1)
Ivabradine	6 (19.4)
ACEI/ARBs/ARNI	23 (74.2)
MRAs	15 (48.4)
Digoxin	4 (12.9)
Diuretics	22 (71.0)
mMRC dyspnea scale, n (%)	
I	11 (35.5)
II	14 (45.2)
III	5 (16.1)
IV	1 (3.2)
Pulmonary function	
FEV_1, %	85.00 (75.00-94.00)
FVC, %	86.00 (78.00-92.00)
FEV_1/FVC, %	79.40 (74.50-83.70)
FEF_{25-75}; %	70.58 ± 27.37
PEF, %	75.74 ± 28.62
Functional tests	
6PBRT, rings	133.48 ± 33.51
6PBRT, % predicted	64.22 ± 14.04
TGlittre, min	3.20 (2.53-4.15)
TGlittre, % predicted	108.39 (88.27-137.19)
6MWD, m	435.17 ± 97.03
6MWD, % predicted	85.08 (69.37-92.92)

Data are expressed as mean ± standard deviation (SD) or median (IQR) unless otherwise indicated. 6MWD, Six-Minute Walk Distance; 6PBRT, 6-Minute Pegboard and Ring Test; ACEI, Angiotensin-Converting Enzyme Inhibitor; ARBs, Angiotensin Receptor Blockers; ARNI, Angiotensin Receptor-Neprilysin Inhibitor; FEF_{25-75}, Forced Expiratory Flow at 25-75%; FEV_1, Forced Expiratory Volume in One Second; FVC, Forced Vital Capacity; LVEF, Left Ventricular Ejection Fraction; mMRC, Modified Medical Research Council; MRAs, Mineralocorticoid Receptor Antagonists; NYHA, New York Heart Association; PEF, Peak Expiratory Flow; TGlittre, Glittre ADL test.

(58.1%). The majority of participants had a dyspnea perception score of mMRC II (45.2%). The mean total number of rings moved in the 6PBRT was 133.48 ± 33.51, with a mean percentage of the predicted 6PBRT value at 64.22 ± 14.04. The median duration for participants to complete the TGlittre was 3.20 (2.53-4.15), and the median percentage of the predicted TGlittre value was 108.39 (88.27-137.19). The mean 6MWD for participants was 435.17 ± 97.03, with a median percentage of the predicted 6MWD value at 85.08 (69.37-92.92).

Figure 1 presents the correlations between the 6PBRT, TGlittre, and 6MWD. The 6PBRT was strongly correlated with TGlittre

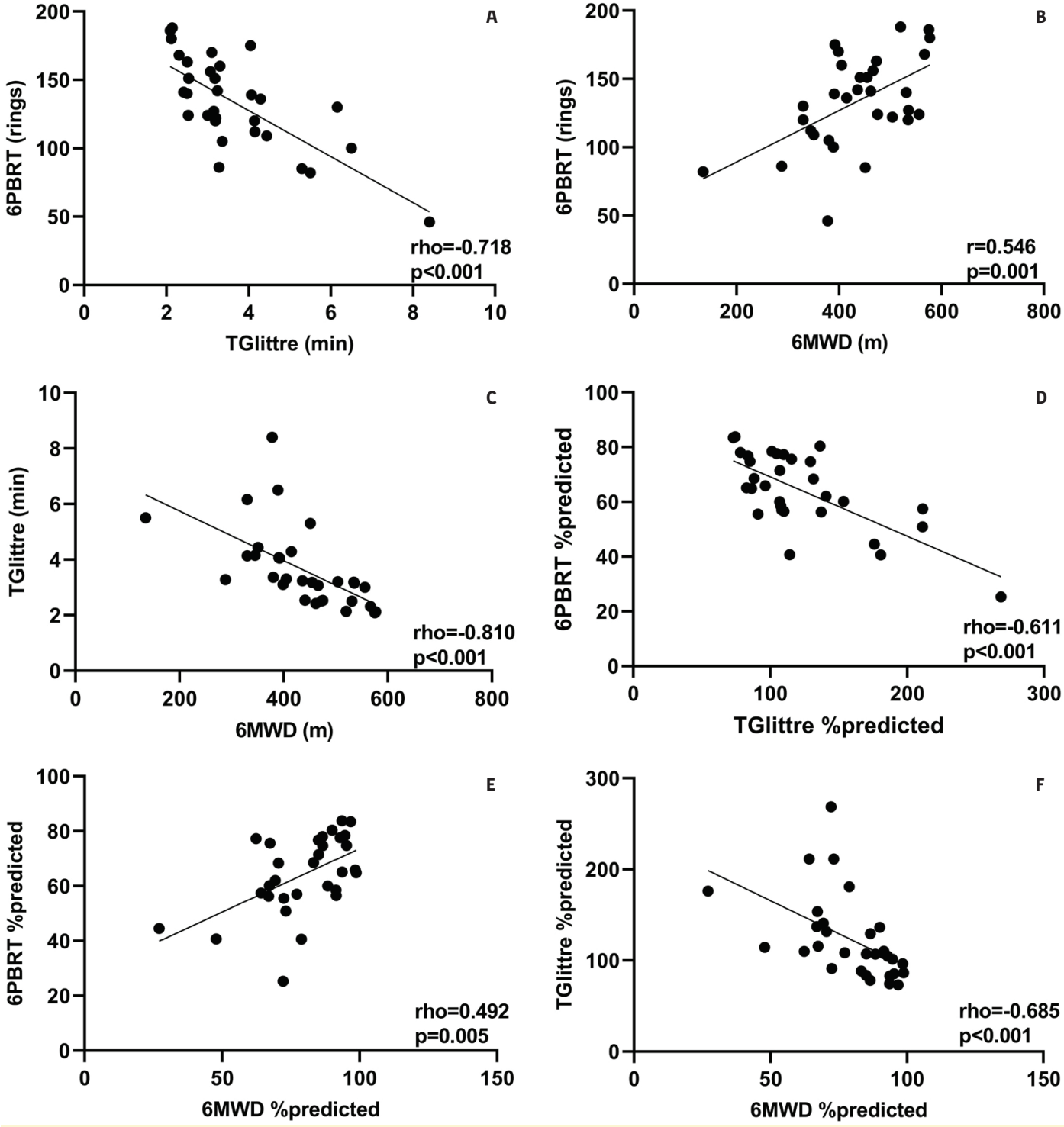

Figure 1. Correlations between: A) 6PBRT and TGlittre, B) 6PBRT and 6MWD, C) TGlittre and 6MWD, D) 6PBRT%$_{predicted}$ and TGlittre%$_{predicted}$, E) 6PBRT%$_{predicted}$ and 6MWD%$_{predicted}$, F) TGlittre%$_{predicted}$ and 6MWD%$_{predicted}$. 6PBRT, 6-Minute Pegboard and Ring test; TGlittre, Glittre Activities of Daily Living Test; 6MWD, 6-Minute Walk Distance.

Table 2. Comparison of Physiological Values Obtained Pre- and Post-Test for 6PBRT, TGlittre, and 6MWT

	6PBRT (n = 31) Mean ± SD or Median (IQR)				TGlittre (n = 31) Mean ± SD or Median (IQR)				6MWT (n = 31) Mean ± SD or Median (IQR)			
	Pre-test	Post-test	t/Z	P	Pre-test	Post-test	t/Z	P	Pre-test	Post-test	t/Z	P
HR (beats/min)	71.55 ± 10.99	74.71 ± 12.46	-3.408	**0.002***	70.90 ± 12.50	89.90 ± 14.29	-9.578	**<0.001***	70.87 ± 11.56	86.32 ± 14.38	-8.464	**<0.001***
SBP (mmHg)	120.13 ± 14.65	127.71 ± 17.14	-4.298	**<0.001***	118.03 ± 15.80	136.87 ± 20.70	-8.316	**<0.001***	119.52 ± 3.41	131.32 ± 3.86	-5.715	**<0.001***
DBP (mmHg)	76.13 ± 8.66	78.71 ± 9.27	-2.515	**0.018***	75.94 ± 9.76	79.97 ± 10.97	-2.890	**0.007***	75.61 ± 10.53	78.48 ± 2.05	-2.048	**0.049***
SpO_2 (%)	96.00 (96.00–97.00)	97.00 (96.00–98.00)	-1.762	0.078**	97.00 (96.00–98.00)	98.00 (96.00–99.00)	-0.579	0.562**	96.00 (95.00–97.00)	98.00 (96.00–98.00)	-2.895	**0.004****
Dyspnea (0–10)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	-2.032	**0.042****	0.00 (0.00–0.00)	1.00 (0.00–4.00)	-3.838	**<0.001****	0.00 (0.00–0.00)	1.00 (00.00–3.00)	-3.749	**<0.001****
Arm Fatigue (0–10)	0.00 (0.00–0.00)	3.00 (2.00–5.00)	-4.640	**<0.001****	0.00 (0.00–0.00)	0.00 (0.00–3.00)	-3.307	**0.001****	NA	NA	NA	NA
Leg Fatigue (0–10)	NA	NA	NA	NA	0.00 (0.00–0.00)	2.00 (0.00–3.00)	-4.219	**<0.001****	0.00 (0.00–0.00)	0.00 (0.00–4.00)	-3.736	**<0.001****
General Fatigue (0–10)	0.00 (0.00–0.00)	0.00 (0.00–3.00)	-3.428	**0.001****	0.00 (0.00–0.00)	2.00 (0.00–3.00)	-3.943	**<0.001****	0.00 (0.00–0.00)	0.00 (0.00–4.00)	-3.528	**<0.001****

Data are expressed as mean ± standard deviation (SD) or median (interquartile range). 6MWT, 6-Minute Walk Test; 6PBRT, 6-Minute Pegboard and Ring Test; DBP, Diastolic Blood Pressure; HR, Heart Rate; NA, Not Applicable; SBP, Systolic Blood Pressure; SpO_2, Peripheral Oxygen Saturation; TGlittre, Glittre ADL test.
*Paired sample *t*-test (t), **Wilcoxon test (Z). *P* < 0.05.

(*rho* = -0.718, *P* < 0.001) and moderately correlated with 6MWD (*r* = 0.546, *P* = 0.001). A very strong correlation was observed between TGlittre and 6MWD (*rho* = -0.810, *P* < 0.001). Additionally, the $6PBRT\%_{predicted}$ was strongly correlated with the $TGlittre\%_{predicted}$ (*rho* = -0.611, *P* < 0.001) and moderately correlated with $6MWD\%_{predicted}$ (*rho* = 0.492, *P* = 0.005). A strong correlation was also found between $TGlittre\%_{predicted}$ and $6MWD\%_{predicted}$ (*rho* = -0.685, *P* < 0.001).

Table 2 presents the comparisons of physiological values obtained before and after the 6PBRT, TGlittre, and 6MWT. Pre-test values of HR, SBP, DBP, SpO_2, dyspnea, and fatigue were similar across the 6PBRT, TGlittre, and 6MWT (*P* > 0.05). Significant differences were observed between pre- and post-test measurements for HR, SBP, DBP, dyspnea, and general fatigue across all three tests (*P* < 0.05). SpO_2 showed a significant difference between pre- and post-6MWT (*P* < 0.05) but remained similar between pre- and post-6PBRT and TGlittre (*P* > 0.05). Significant differences were found in arm fatigue between the pre- and post-6PBRT and TGlittre (*P* < 0.05) and in leg fatigue between the pre- and post-TGlittre and 6MWT (*P* < 0.05).

Table 3 presents the comparisons of physiological changes among the 6PBRT, TGlittre, and 6MWT. The percentage of maximal heart rate ($HR_{max\%}$) differed significantly among the tests. $HR_{max\%}$ was lower in the 6PBRT than in both the TGlittre (*P* < 0.001) and 6MWT (*P* < 0.001). However, $HR_{max\%}$ was similar between the TGlittre and 6MWT (*P* = 0.347). Significant differences were observed in changes in HR, SBP, SpO_2, and dyspnea among the tests (*P* < 0.05). Post hoc analysis revealed that the change in HR was lower in the 6PBRT compared to both the TGlittre (*P* < 0.001) and the 6MWT (*P* < 0.001). HR changes were similar between the TGlittre and 6MWT (*P* = 0.344). The change in SBP was higher in the TGlittre than in the 6PBRT (*P* < 0.001) and 6MWT (*P* = 0.027), while SBP changes were similar between the 6PBRT and 6MWT (*P* = 0.264). The significant difference in SpO_2 changes across the tests disappeared after post hoc analysis. The change in dyspnea was lower in the 6PBRT than in the TGlittre (*P* = 0.001) and 6MWT (*P* = 0.047). The change in dyspnea was similar between the TGlittre and 6MWT (*P* = 0.612). No significant differences were found in changes in DBP and general fatigue among the 6PBRT, TGlittre, and 6MWT (*P* > 0.05).

Discussion

The main finding of our study is that there were statistically significant associations between upper extremity function, ADLs, and functional capacity in patients with HFrEF. Additionally, the 6PBRT, TGlittre, and 6MWT elicited significant acute changes in physiological values. The percentage of maximum heart rate achieved was lowest in the 6PBRT. Changes in HR and dyspnea were also lowest in the 6PBRT, while the change in SBP was highest in the TGlittre. Changes in DBP and general fatigue were similar across the tests.

Takeda et al.[6] found a correlation between upper extremity function and upper extremity ADLs assessed by activity counts in patients with COPD. Additionally, Calik-Kutukcu et al.[24] showed a correlation between upper extremity function and upper extremity ADLs assessed by the ADL simulation test in patients with moderate to severe COPD. This study similarly

Table 3. Comparison of Physiological Changes Between the 6PBRT, TGlittre, and 6MWT

	6PBRT (n = 31) Mean ± SD or Median (IQR)	TGlittre (n = 31) Mean ± SD or Median (IQR)	6MWT (n = 31) Mean ± SD or Median (IQR)	*P*
$HR_{max\%}$	45.43 ± 7.42[a]	54.63 ± 8.28	52.46 ± 8.31[c]	**<0.001***
ΔHR (beats/min)	3.16 ± 5.17[a]	19.00 ± 11.05	15.45 ± 10.17[c]	**<0.001***
ΔSBP (mmHg)	7.58 ± 9.82[a]	18.84 ± 12.61[b]	11.81 ± 11.50	**<0.001***
ΔDBP (mmHg)	2.58 ± 5.71	4.03 ± 7.77	2.87 ± 7.81	0.663*
ΔSpO_2 (%)	0.00 (0.00-1.00)	0.00 (-1.00-1.00)	1.00 (0.00-2.00)	**0.015****
ΔDyspnea (0-10)	0.00 (0.00-0.00)[a]	1.00 (000-4.00)	1.00 (0.00-3.00)[c]	**<0.001****
ΔGeneral Fatigue (0-10)	0.00 (0.00-3.00)	2.00 (0.00-3.00)	1.00 (0.00-3.00)	0.446**

Data are expressed as mean ± standard deviation (SD) or median (interquartile range). 6MWT, 6-Minute Walk Test; 6PBRT, 6-Minute Pegboard and Ring Test; DBP, Diastolic Blood Pressure; HR, Heart Rate; SBP, Systolic Blood Pressure; SpO_2, Peripheral Oxygen Saturation; TGlittre, Glittre ADL test. D, change from pre-test to post-test values.
*Repeated measures Analysis of Variance (ANOVA), **Friedman test. [a]Significant difference between 6PBRT and TGlittre; [b]Significant difference between TGlittre and 6MWT; [c]Significant difference between 6PBRT and 6MWT. $P < 0.05$.

demonstrated that upper extremity function was correlated with ADLs measured by the TGlittre in patients with HFrEF. Collectively, this evidence suggests that higher upper extremity function is associated with better ADLs in patients with HFrEF.

Ozsoy et al.[7] reported that functional capacity assessed by the 6MWT was one of the determinants of upper extremity exercise capacity assessed by the 6PBRT in patients with COPD. This similarly study found that upper extremity function correlated with functional capacity assessed by the 6MWT, indicating that upper extremity function tends to impact functional capacity in patients with HFrEF.

Most patients with HF have report difficulty performing one or more ADLs, with these difficulties often worsening over time.[25] It has also been shown that patients with HF tend to reduce the intensity of their effort and increase the time required to complete ADLs when they can self-adjust exercise intensity.[26] Since patients with HF experience difficulties in ADLs that require both upper and lower extremity function—such as carrying objects, doing housework and heavy labor, and performing personal care—the functionality of the upper extremities is crucial for maintaining ADLs in this population.[27] Paneroni et al.[28] demonstrated that short-term cardiac rehabilitation improved the performance of routine ADLs, significantly decreasing the cumulative time required to complete these activities in elderly patients with HF. Additionally, Nyquist-Battie et al.[29] found that upper extremity exercise training increased cardiopulmonary exercise test duration in patients with HF. Considering these findings, the relationships between upper extremity function, ADLs, and functional capacity observed in patients with HFrEF in this study suggest that upper extremity training should be incorporated into cardiac rehabilitation programs.

HR, SBP, DBP, dyspnea, and fatigue significantly increased after the 6PBRT, the TGlittre, and the 6MWT, indicating that all three tests create physiological load. The greater systolic blood pressure response observed in the TGlittre compared to the 6PBRT and 6MWT may be partly due to the involvement of more muscle mass, as both arms and legs are used.[30] However, the lower physiological response observed in the 6PBRT compared to the TGlittre and the 6MWT suggests that the 6PBRT can be used to assess physical function with lower physiological demand in patients with HFrEF. Further studies assessing physiological demand using a portable gas analyzer are needed to support these findings.

This study has several limitations. First, due to the cross-sectional design, causal relationships between these associations cannot be established. Second, although the post-hoc power analysis indicated adequate power and the tests were performed randomly, studies with larger sample sizes that control for confounders such as age, gender, body mass index, medication, and physical activity level would strengthen these results by reducing potential bias. Lastly, since this study included only patients with HfrEF, the findings may not be generalizable to all phenotypes of HF. Future studies with larger sample sizes are required to investigate the associations between upper extremity function, ADLs, and functional capacity in patients with HF with mildly reduced and preserved ejection fraction.

In a clinical context, the moderate to strong correlations between upper extremity function, ADLs, and functional capacity in patients with HFrEF suggest that changes in upper extremity function are closely linked to a patient's ability to perform daily tasks and maintain physical capacity. Identifying declines in upper extremity function may serve as an early indicator of reduced ADLs and functional capacity, potentially allowing for proactive measures to prevent further deterioration of physical function. Additionally, incorporating upper extremity exercises into cardiac rehabilitation programs could contribute to improvements in ADLs and functional capacity in patients with HFrEF. Furthermore, the fact that the 6PBRT requires lower physiological demand suggests that clinicians and researchers can use it safely to predict ADL capability and functional capacity in patients with HFrEF, particularly in those with more severe disease.

Conclusion

This study demonstrates that upper extremity function is associated with ADLs and functional capacity in patients with

HFrEF. The 6PBRT requires lower cardiopulmonary demand than the TGlittre and the 6MWT in this patient population.

Ethics Committee Approval: Ethics committee approval was obtained from Dokuz Eylül Dokuz Eylül University Non-Invasive Research Ethical Committee (Approval Number: 2023/03-05, Date: 18.01.2023).

Informed Consent: All participants provided written informed consent.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – A.T.E., İ.Ö., B.Ö.K.; Design – A.T.E., B.Ö.K., E.Ö., S.A., B.Ş., İ.Ö., B.A., M.B.Y., S.S.; Supervision – S.S.; Materials – E.Ö., B.A., B.Ş., M.B.Y.; Data Collection and/or Processing – A.T.E., B.Ö.K., S.A.; Analysis and/or Interpretation – A.T.E.; Literature Review – A.T.E., B.Ö.K., İ.Ö., S.A.; Writing – A.T.E.; Critical Review – A.T.E., B.Ö.K., E.Ö., S.A., B.Ş., İ.Ö., B.A., M.B.Y., S.S.

Use of AI for Writing Assistance: Artificial intelligence (AI)-assisted technologies, such as Large Language Models (LLMs), chatbots, or image generators, were not used in the production of this study.

Conflict of Interest: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study received no financial support.

References

1. Bragazzi NL, Zhong W, Shu J, et al. Burden of heart failure and underlying causes in 195 countries and territories from 1990 to 2017. *Eur J Prev Cardiol*. 2021;28(15):1682-1690. [CrossRef]
2. G-CHF Investigators; Joseph P, Roy A, et al. Global variations in heart failure etiology, management, and outcomes. *JAMA.* 2023;329(19):1650-1661. Erratum in: *JAMA.* 2023;330(9):880.
3. Keteyian SJ, Marks CR, Brawner CA, Levine AB, Kataoka T, Levine TB. Responses to arm exercise in patients with compensated heart failure. *J Cardiopulm Rehabil*. 1996;16(6):366-371. [CrossRef]
4. Konishi M, Akiyama E, Matsuzawa Y, et al. Prognostic impact of upper and lower extremity muscle mass in heart failure. *ESC Heart Fail*. 2023;10(1):732-737. [CrossRef]
5. Janaudis-Ferreira T, Beauchamp MK, Goldstein RS, Brooks D. How should we measure arm exercise capacity in patients with COPD? A systematic review. *Chest*. 2012;141(1):111-120. [CrossRef]
6. Takeda K, Kawasaki Y, Yoshida K, et al. The 6-minute pegboard and ring test is correlated with upper extremity activity of daily living in chronic obstructive pulmonary disease. *Int J Chron Obstruct Pulmon Dis*. 2013;8:347-351. [CrossRef]
7. Ozsoy I, Ozcan Kahraman B, Ozsoy G, et al. Determinants of the 6-minute pegboard and ring test as an unsupported upper-extremity exercise capacity measure in older adults with chronic obstructive pulmonary disease. *Eur Geriatr Med*. 2018;9(6):863-870. [CrossRef]
8. Kahraman BÖ, Özsoy İ, Tanrıverdi A, et al. Validity and reliability of the 6-minute pegboard ring test in patients with pulmonary hypertension. *Turk J Physiother Rehabil.* 2020;31(2):210-217. [CrossRef]
9. McDonagh TA, Metra M, Adamo M, et al; ESC Scientific Document Group. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. *Eur Heart J.* 2021;42(36):3599-3726. Erratum in: *Eur Heart J.* 2021;42(48):4901.
10. Heidenreich PA, Bozkurt B, Aguilar D, et al. 2022 American College of Cardiology/ American Heart Association/ Heart Failure Society of America guideline for the management of heart failure: Executive summary. *J Card Fail*. 2022;28(5):810-830. [CrossRef]
11. Bennett JA, Riegel B, Bittner V, Nichols J. Validity and reliability of the NYHA classes for measuring research outcomes in patients with cardiac disease. *Heart Lung*. 2002;31(4):262-270. [CrossRef]
12. Miller MR, Hankinson J, Brusasco V, et al. Standardisation of spirometry. *Eur Respir J*. 2005;26(2):319-338. [CrossRef]
13. Uszko-Lencer NHMK, Mesquita R, Janssen E, et al. Reliability, construct validity and determinants of 6-minute walk test performance in patients with chronic heart failure. *Int J Cardiol*. 2017;240:285-290. [CrossRef]
14. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: Guidelines for the six-minute walk test. *Am J Respir Crit Care Med.* 2002;166(1):111-117. Erratum in: *Am J Respir Crit Care Med.* 2016;193(10):1185. [CrossRef]
15. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. *Am J Respir Crit Care Med.* 1998;158(5 Pt 1):1384-1387. Erratum in: *Am J Respir Crit Care Med.* 2020;201(3):393. [CrossRef]
16. Valadares YD, Corrêa KS, Silva BO, Araujo CLP, Karloh M, Mayer AF. Applicability of activities of daily living tests in individuals with heart failure. *Rev Bras Med Esporte.* 2011;17(5):310-314. [CrossRef]
17. Leite J, Araújo BTS, SoaresBrandão SC, et al. Association between performance on the Glittre ADL-test and the functional capacity of patients with HF: A cross-sectional study. *Physiother Theory Pract*. 2022;38(2):337-344. [CrossRef]
18. Skumlien S, Hagelund T, Bjørtuft O, Ryg MS. A field test of functional status as performance of activities of daily living in COPD patients. *Respir Med*. 2006;100(2):316-323. [CrossRef]
19. Reis CMD, Karloh M, Fonseca FR, Biscaro RRM, Mazo GZ, Mayer AF. Functional capacity measurement: Reference equations for the Glittre Activities of Daily Living test. *J Bras Pneumol*. 2018;44(5):370-377. [CrossRef]
20. Zhan S, Cerny FJ, Gibbons WJ, Mador MJ, Wu YW. Development of an unsupported arm exercise test in patients with chronic obstructive pulmonary disease. *J Cardiopulm Rehabil*. 2006;26(3):180-190. [CrossRef]
21. Lima VP, Almeida FD, Janaudis-Ferreira T, et al. Reference values for the six-minute pegboard and ring test in healthy adults in Brazil. *J Bras Pneumol*. 2018;44(3):190-194. [Portuguese] [CrossRef]
22. Seki KLM, Queiróz APL, Costa AS, et al. Physical capacity, respiratory and peripheral muscle strength in heart failure. *Rev Bras Med Esporte.* 2020;26(4):289-293. [CrossRef]
23. Campbell MJ. *Statistics at Square One*. 12th ed. Hoboken, NJ: Wiley-Blackwell; 2021. [CrossRef]
24. Calik-Kutukcu E, Arikan H, Vardar-Yagli N, et al. Association between 6 min pegboard and ring test and arm performance in GOLD stage II-III patients. *Wien Klin Wochenschr*. 2021;133(11-12):594-601. [CrossRef]
25. Dunlay SM, Manemann SM, Chamberlain AM, et al. Activities of daily living and outcomes in heart failure. *Circ Heart Fail*. 2015;8(2):261-267. [CrossRef]
26. Mapelli M, Salvioni E, Bonomi A, et al. How patients with heart failure perform daily life activities: An innate energy-saving strategy. *Circ Heart Fail*. 2020;13(11):e007503. [CrossRef]
27. Niklasson A, Maher J, Patil R, et al. Living with heart failure: Patient experiences and implications for physical activity and daily living. *ESC Heart Fail*. 2022;9(2):1206-1215. [CrossRef]
28. Paneroni M, Scalvini S, Corrà U, et al. The impact of cardiac rehabilitation on activities of daily life in elderly patients with heart failure. *Front Physiol*. 2022;12:785501. [CrossRef]
29. Nyquist-Battie C, Fletcher GF, Fletcher B, Carlson JM, Castello R, Oken K. Upper-extremity exercise training in heart failure. *J Cardiopulm Rehabil Prev*. 2007;27(1):42-45. [CrossRef]
30. Mitchell JH, Payne FC, Saltin B, Schibye B. The role of muscle mass in the cardiovascular response to static contractions. *J Physiol*. 1980;309:45-54. [CrossRef]