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ORIGINAL RESEARCH

Health-Related Physical Fitness Status and Associated Factors in Breast Cancer Patients Undergoing Chemotherapy: A Cross-Sectional Study

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Background: Breast cancer has the highest incidence among women. Exercise interventions are increasingly recognized as key strategies to prevent and alleviate chemotherapy side effects. Pre-exercise health-related physical fitness (HRPF) assessments are critical forensuring safety. However, investigations on HRPF during chemotherapy and its influencing factors remain limited.

Purpose: To evaluate HRPF status and its influencing factors in breast cancer patients undergoing chemotherapy, informing tailored exercise rehabilitation programs.

Patients and Methods: A cross-sectional study was conducted with 230 hospitalized breast cancer patients undergoing chemotherapy in a tertiary hospital in Tongling, China. Data included a general information questionnaire, the International Physical Activity Questionnaire–Short Form (IPAQ-SF), and standardized physical measurements across five HRPF dimensions.

Results: Descriptive analysis indicated that HRPF levels were suboptimal among participants. Regression analysis identified significant predictors of HRPF, including age, physical activity level, sedentary time, hemoglobin level, menopausal status, breast cancer subtypes and chemotherapy regimen ($P < 0.001$).

Conclusion: The level of HRPF among breast cancer patients undergoing chemotherapy remains suboptimal. Healthcare professionals should develop individualized exercise rehabilitation programs based on each patient's HRPF status and implement early assessment and intervention strategies targeting modifiable factors to enhance HRPF outcomes.

Keywords: breast cancer, chemotherapy, HRPF, exercise rehabilitation

Introduction

Breast cancer is the most commonly diagnosed malignancy in women, accounting for nearly one-quarter of all cancer cases, with an estimated 2.3 million new diagnoses worldwide in 2022.[1] In China, the National Cancer Center reported approximately 357,200 new cases in 2022, ranking breast cancer as the second most prevalent malignancy among women.[2] Chemotherapy remains a cornerstone of treatment, effectively reducing recurrence and improving five-year survival.[3,4] Nevertheless, chemotherapy often leads to adverse effects—including altered body composition,[5] reduced cardiopulmonary[6] and muscular function,[7] and peripheral neuropathy[8]—that can compromise patients' treatment adherence and quality of life. Health-related physical fitness (HRPF), which includes cardiorespiratory endurance, muscular strength and endurance, flexibility, balance, and body composition, is a core determinant of functional health. It reflects an individual's capacity to perform daily activities and cope with physiological stressors.[9–11] In breast cancer patients, HRPF is closely linked to maintaining independence, improving treatment tolerance, and reducing the risk of comorbidities. According to the 2023 Guidelines for Integrated Cancer Therapy in China, comprehensive HRPF assessment is essential for designing safe and effective exercise interventions.[12,13]

Previous studies have mainly emphasized exercise-based interventions to enhance tumor response,[14] support chemotherapy tolerance,[15] and mitigate declines in specific HRPF domains.[16] However, few have comprehensively evaluated all five HRPF components or systematically examined influencing factors during chemotherapy. The present study therefore

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investigates the HRPF profile of breast cancer patients undergoing chemotherapy and explores associated predictors, aiming to provide an evidence-based foundation for developing tailored exercise rehabilitation programs.

Materials and Methods

Participants

A convenience sampling method was employed to recruit breast cancer patients receiving inpatient chemotherapy at a tertiary hospital in Tongling, Anhui Province, China, between August 2024 and March 2025. Inclusion criteria were as follows: (1) diagnosis of stage I–III breast cancer in accordance with the *2024 Guidelines of the Chinese Anti-Cancer Association*; (2) female, aged ≥18 years, and aware of their diagnosis; (3) able to independently complete all HRPF assessments; and (4) willing to participate with informed consent. Exclusion criteria included: (1) language or hearing impairments preventing comprehension and response; (2) patients with severe illness who are bedridden; (3) serious complications such as cardiovascular, cerebrovascular, renal, ocular, foot, or neurological conditions affecting physical performance; (4) temporary unsuitability for physical activity due to conditions such as flap necrosis, subcutaneous effusion, skin grafts, or breast reconstruction using a latissimus dorsi flap; and (5) hemoglobin levels below 60 g/L (Severely anemic patients are recommended to remain largely bedridden and to limit physical exertion).[17]

The sample size was determined using the formula $n = [(Z_{\alpha/2} \times \sigma)/\delta]^2$.[18] Here, σ was set at 3.86, based on previously published data reporting the standard deviation of muscular strength[19]—a key component of HRPF. The allowable error δ was set at 0.55,[20] corresponding to 3% of the mean muscular strength (18 kg × 0.03) reported in prior studies.[19] $Z_{\alpha/2}$ was 1.96, yielding an estimated sample size of 190 participants. Considering a 20% potential dropout rate, the final sample size was adjusted to 230 participants. Ethical approval for the study was granted by the university's ethics committee (Approval No. [2022]102), and all participants provided written informed consent prior to enrollment.

Research Tools

General Information Questionnaire

A self-designed general information questionnaire, developed by the research team based on a review of relevant literature, was used to collect demographic and clinical characteristics of the participants. Demographic variables included age, employment status, place of residence, educational level, and monthly household income, menopausal status. Clinical data encompassed the presence of comorbid chronic diseases, chemotherapy regimen, tumor stage, hemoglobin levels, and breast cancer subtypes. The content validity of the questionnaire was assessed by ten experts in the fields of oncology rehabilitation and exercise rehabilitation. The item-level content validity index (I-CVI) ranged from 0.80 to 1.00, the scale-level content validity index (S-CVI/Ave) was 0.93, and the Kappa statistic (K) ranged from 0.79 to 1.00, indicating good content validity.

Physical Activity Assessment

Physical activity levels were assessed using the Chinese version of the International Physical Activity Questionnaire–Short Form (IPAQ-SF), adapted by Qu Ningning et al,[21] which is widely used to evaluate the frequency and duration of physical activities across three intensity levels over the past seven days: vigorous-intensity, moderate-intensity, and walking. The questionnaire includes seven items and also records average daily sedentary time. The IPAQ-SF has demonstrated good reliability (test-retest reliability: 0.63–0.89) and criterion validity (r = 0.72). The test-retest reliability was assessed for energy expenditure associated with total physical activity, vigorous-intensity activity, moderate-intensity activity, walking, and sedentary time.

The validity study used energy expenditure measured by the Caltrac™ accelerometer and physical activity logs as the reference standards. Weekly energy expenditure for each activity level was calculated using the following formula: MET × days per week × minutes per day, where the metabolic equivalent task (MET) values were 8.0 for vigorous-intensity, 4.0 for moderate-intensity, and 3.3 for walking. Based on WHO guidelines, participants were categorized into low, moderate, or high physical activity levels. A high activity level was defined as meeting either of the following: (1) vigorous-intensity activity ≥3 days/week with ≥1500 MET-min/week; or (2) any combination of walking, moderate-, or vigorous-intensity activity on ≥7 days/week with a minimum total of 3000 MET-min/week. A moderate activity level was defined as meeting one of the following: (1) vigorous-intensity activity ≥3 days/week for ≥20 minutes/day; (2) moderate-intensity activity or walking ≥5 days/week for ≥30 minutes/

day; or (3) any combination of walking, moderate-, or vigorous-intensity activity ≥5 days/week totaling at least 600 MET-min /week. Participants not meeting any of these criteria were classified as having a low activity level.[22]

HRPF Assessment

HRPF was assessed in accordance with the *ACSM's Guidelines for Exercise Testing and Prescription (10th edition)* and the *Comprehensive Cancer Rehabilitation Guidelines (CACA, 2023)*.[23,24] The assessment encompassed five key dimensions: body composition, cardiorespiratory fitness, muscular strength and endurance, flexibility, and balance.

Body composition was evaluated using body mass index (BMI) and waist-to-hip ratio (WHR). BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). WHR was obtained by dividing the waist circumference (measured at the narrowest point or 1–2cm above the navel) by the hip circumference (measured at the widest part of the buttocks).

Cardiorespiratory fitness was assessed via forced vital capacity (mL) using a portable spirometer. Participants performed maximal exhalation following deep inhalation; the best value from two trials was recorded. In addition, the 2-minute step test (step) was used, during which participants marched in place, lifting the knees to a predetermined height. The number of right knee lifts within 2 minutes was recorded.

Muscular strength and endurance were measured using handgrip strength and the 30-second chair stand test (number). Handgrip strength (kg) (dominant hand) was tested using a digital dynamometer with the arm extended and not touching the torso; the best of two trials was recorded. Lower-limb muscular endurance was evaluated using the 30-second chair stand test, in which participants rose to a full stand and returned to a seated position as many times as possible with arms crossed at the chest; the higher value of two trials was used.

Flexibility was assessed via the back scratch test (cm) (upper body flexibility) and the chair sit-and-reach test (cm) (lower body flexibility). In the back scratch test, participants reached behind the back with both hands—one over the shoulder and the other from below. The distance between the middle fingertips was measured using a soft ruler; zero indicated fingertip contact, positive values indicated overlap, and negative values indicated a gap. For the chair sit-and-reach, participants sat on a chair and extended one leg forward with the toe pointing up. They reached toward the toes, and the fingertip-to-toe distance was measured—positive for reaching past the toes and negative for falling short.

Balance was assessed by measuring the load distribution difference between both feet (%) using Hiscan-HS6060 plantar pressure, gait, and balance system (Haikang Technology Co., Ltd., Anhui, China). Participants stood naturally on the device; after maintaining stability for 3 seconds, the weight distribution difference was recorded twice, with the best result used (larger differences indicating poorer balance).[25] The one-leg stance test(s) with eyes closed was also conducted: after finding balance with eyes open, participants closed their eyes on command and the duration of one-leg stance was recorded in seconds. The best of two trials was used.

All tests were conducted under the supervision of trained nursing staff and rehabilitation graduate students to ensure participant safety throughout the procedures.

Data Collection Procedures

Data collection was conducted by members of the research team who had received standardized training. All questionnaires were administered using uniform instructions and explanatory notes. For elderly participants or those with limited literacy, trained interviewers provided face-to-face assistance, explaining each item and recording responses to ensure data quality. Upon completion, the questionnaires were reviewed on site by the interviewers, and any incomplete or invalid entries were immediately corrected or re-administered to ensure the objectivity and validity of the responses. A total of 235 questionnaires were distributed and all were returned, resulting in a response rate of 100%. After excluding five invalid questionnaires, the effective response rate was 97.9%. Prior to the HRPF assessments, a single trained investigator demonstrated each movement to the participants. Two researchers independently recorded the results and cross-checked the data to ensure consistency, objectivity, and accuracy of the measurements.

Statistical Methods

Data were independently entered into Epidata by two researchers, and software was used to compare differences to ensure the accuracy of data entry. Statistical analyses were performed using SPSS version 26.0. The normality of continuous data was assessed using the Shapiro–Wilk test. Normally distributed continuous data were described as means ± standard deviations, and differences between groups were compared using independent sample *t*-tests and one-way analysis of variance (ANOVA). Skewed data were presented as M (P25, P75), and differences were assessed using Mann–Whitney *U*-tests and Kruskal–Wallis *H*-tests. Categorical data were expressed as frequencies and percentages. In the case of significant ANOVA results, post-hoc pairwise comparisons were conducted using Tukey's Honestly Significant Difference (HSD) test. For significant Kruskal–Wallis results, post-hoc analyses were performed using Dunn's test with a Bonferroni correction to account for multiple comparisons. The relationship between sedentary time and various health-related fitness indicators was examined using Spearman correlation analysis. Variables showing statistical significance in the univariate analysis, as well as those identified as relevant in the correlation analysis, were included in the multivariate analysis. Multiple linear regression was then employed to identify the factors influencing the dependent variable. Prior to analysis, key assumptions for MLR were checked, including linearity, absence of multicollinearity (variance inflation factor [VIF] < 10), normality of residuals (Q-Q plot and Shapiro–Wilk test), homoscedasticity (Breusch-Pagan test), and independence of errors (Durbin-Watson test). In the multivariate regression analysis, the enter method was initially employed for variable selection. When the variance inflation factor (VIF) exceeded 5, a stepwise regression method was applied. A significance level of $\alpha = 0.05$ was used, with $P < 0.05$ considered statistically significant.

Results

General Characteristics of the Study Participants

A total of 230 female breast cancer patients participated in the HRPF survey. The participants ranged in age from 27 to 74 years, with a median age of 54 years (interquartile range: 47 to 59.25). Further general characteristics are presented in Table 1.

HRPF Status During Chemotherapy in Breast Cancer Patients

The HRPF parameters of 230 breast cancer patients undergoing chemotherapy were assessed as follows: body mass index (BMI) was 23.8 kg/m^2 (interquartile range: 21.575–25.200), waist-to-hip ratio was 0.85 (0.8275–0.88), handgrip strength was 18.150 kg (16.975–20.125), and 13.00 repetitions (11.00–16.00) were completed in the 30-second chair stand test. The score for the back scratch test was –11.00 cm (–14.00 to –8.00) and the chair sit-and-reach test was –5.00 cm (–6.00 to –4.00). Vital capacity was recorded at 1880 mL (1740–2030), the load distribution difference between both feet was 8.00% (5.00–9.00), and one-leg stance with eyes closed lasted 6.40 seconds (5.00–8.20). Participants completed (88.79 ± 13.168) steps in the 2-minute step test. Detailed data are presented in Table 1.

Univariate Analysis of HRPF During Chemotherapy in Breast Cancer Patients

Univariate analysis revealed that hemoglobin levels, breast cancer subtypes, menopausal status, and physical activity were significantly associated with differences in body composition (BMI) among breast cancer patients undergoing chemotherapy (P<0.05). Hemoglobin levels, physical activity, breast cancer subtypes, menopausal statusand and chemotherapy regimen were significantly associated with waist-to-hip ratio (P<0.05). Upper body muscular strength (handgrip strength) was significantly influenced by chemotherapy regimen, hemoglobin levels, menopausal status, and physical activity (P<0.05). Lower body muscular strength, as assessed by the 30-second chair stand test, was significantly associated with age, hemoglobin levels, menopausal status, and physical activity (P<0.05). Flexibility (as measured by the back scratch test and the chair sit-and-reach test) was significantly influenced by chronic comorbidities, age, educational level, household income, hemoglobin levels, breast cancer subtypes, menopausal status, and physical activity (P<0.05). Cardiorespiratory fitness (as assessed by vital capacity and the 2-minute step test) was significantly associated with chronic comorbidities, age, educational level, household income, chemotherapy regimen, hemoglobin levels, breast cancer subtypes, menopausal status, and physical activity (P<0.05). Balance-related fitness indicators (load distribution

Table 1 Current Status of HRPF and Univariate Analysis During Chemotherapy in Breast Cancer Patients (n = 230)

Variables	n (%)	BMI [kg/m^2, M (P25, P75)]	WHR [M (P25, P75)]	Handgrip Strength [kg, M (P25, P75)]	30-Second Chair Stand Text [number, M (P25, P75)]	Back Scratch Test [cm, M (P25, P75)]	Chair Sit-and-Reach Test [cm, M (P25, P75)]	Forced Vital Capacity [mL, M (P25, P75)]	2-Minute Step Test [step, (Mean ±SD)]	Load Distribution Difference Between Both Feet [%, M (P25, P75)]	One-Leg Stance Test with Eyes Closed [s, M (P25, P75)]
Age (Year)											
<40	21 (9.10)	22.90 (21.40, 24.25)	0.83 (0.815, 0.86)	18.20 (16.95, 22.40)	14.00 (12.00, 16.50)	−3.00 (−6.00, 0.00)	−1.00 (−3.00, 0.00)	2110 (2000, 2375)	104.43±9.24	2.00 (2.00, 3.00)	10.60 (10.35, 11.55)
40–49	55 (23.90)	23.80 (21.30, 25.10)	0.85 (0.83, 0.88)	18.40 (17.80, 20.30)	14.00 (12.00, 16.00)	−9.00 (−10.00, −6.00)	−4.00 (−5.00, −3.00)	2030 (1890, 2150)	95.07±11.47	6.00 (5.00, 7.00)	8.10 (6.90, 9.20)
50–59	97 (42.20)	23.80 (21.90, 25.20)	0.85 (0.82, 0.87)	18.00 (16.90, 20.55)	13.00 (11.00, 15.50)	−12.00 (−3.00, −9.00)	−5.00 (−6.00, −5.00)	1810 (1735, 1995)	87.90±11.09	8.00 (6.00, 9.00)	6.20 (5.25, 7.30)
≥60	57 (24.80)	24.20 (21.30, 25.20)	0.86 (0.83, 0.89)	18.00 (16.90, 20.05)	12.00 (10.00, 14.00)	−15.00 (−16.00, −12.00)	−6.00 (−7.00, −6.00)	1700 (1590, 1840)	78.47±10.03	10.00 (9.00, 12.00)	4.50 (3.60, 5.15)
Test statistic		1.925[b]	3.819[b]	2.474[b]	12.459[b]	95.889[b]	94.021[b]	87.201[b]	38.592[d]	140.164[b]	140.42[b]
P		0.588	0.282	0.48	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Marital status											
Single	31 (13.50)	23.80 (22.10, 25.20)	0.85 (0.83, 0.88)	18.20 (16.50, 19.20)	13.00 (12.00, 16.00)	−10.00 (−15.00, −8.00)	−5.00 (−7.00, −4.00)	1850 (1740, 2050)	89.42±16.58	8.00 (5.00, 9.00)	6.40 (5.30, 8.20)
Married	199 (86.50)	23.90 (21.50, 25.20)	0.85 (0.82, 0.87)	18.10 (17.00, 20.30)	13.00 (11.00, 16.00)	−11.00 (−14.00, −8.00)	−5.00 (−6.00, −4.00)	1880 (1740, 2030)	88.69±12.60	8.00 (5.00, 9.00)	6.40 (4.90, 8.10)
Test statistic		−0.199[a]	−0.328[a]	−1.405[a]	−0.277[a]	−0.205[a]	−0.635[a]	−0.255[a]	0.235[c]	−0.06[a]	−0.501[a]
P		0.842	0.743	0.16	0.782	0.837	0.525	0.798	0.815	0.952	0.617
Residence											
Rural	146 (63.50)	23.95 (21.58, 25.20)	0.85 (0.83, 0.88)	18.15 (17.08, 20.10)	13.00 (12.00, 16.00)	−11.00 (−14.00, −8.00)	−5.00 (−6.00, −4.00)	1880 (1740, 2030)	88.73±13.47	8.00 (5.00, 9.00)	6.40 (5.00, 8.40)
City	84 (36.50)	23.75 (21.53, 24.90)	0.85 (0.82, 0.87)	18.10 (16.90, 20.73)	13.00 (11.00, 16.00)	−11.00 (−13.00, −8.00)	−5.00 (−6.00, −4.00)	1860 (1732, 2030)	88.89±12.71	8.00 (6.00, 9.00)	6.45 (5.00, 8.00)
Test statistic		−0.37[a]	−0.52[a]	−0.181[a]	−0.563[a]	−0.243[a]	−0.438[a]	−0.274[a]	−0.092[c]	−0.152[a]	−0.176[a]
P		0.712	0.63	0.856	0.573	0.808	0.661	0.784	0.927	0.879	0.86
Occupational status											
Unemployed	174 (75.70)	23.90 (21.60, 25.20)	0.85 (0.83, 0.88)	18.20 (16.98, 20.10)	13.00 (11.00, 16.00)	−11.00 (−13.00, −8.00)	−5.00 (−6.00, −4.00)	1880 (1750, 2030)	88.83±12.88	8.00 (5.00, 9.00)	6.35 (5.10, 8.25)
Employed	56 (24.30)	23.65 (21.35, 25.03)	0.85 (0.82, 0.87)	18.00 (16.95, 21.70)	13.00 (11.00, 16.00)	−11.50 (−14.00, −8.00)	−5.00 (−6.00, −4.00)	1855 (1710, 2057.5)	88.64±14.16	7.00 (6.00, 9.75)	6.95 (5.00, 8.00)
Test statistic		−0.701[a]	−0.234[a]	−0.169[a]	−0.036[a]	−0.87[a]	−0.795[a]	−0.38[a]	0.094[c]	−0.301[a]	−0.225[a]
P		0.483	0.815	0.866	0.971	0.384	0.427	0.704	0.925	0.763	0.822
Education level											
Primary and below	36 (15.70)	24.30 (21.35, 25.28)	0.86 (0.83, 0.89)	18.10 (16.58, 20.45)	13.00 (11.00, 14.00)	−13.00 (−15.00, −10.00)	−6.00 (−7.00, −5.00)	1795 (1702.50, 1950)	85.81±12.44	9.00 (8.00, 10.75)	5.25 (4.13, 6.78)
Middle school	92 (40.0)	23.75 (21.43, 25.05)	0.85 (0.82, 0.87)	17.90 (17.00, 20.10)	13.00 (11.00, 15.75)	−12.00 (−14.00, −8.00)	−5.00 (−6.00, −4.00)	1850 (1720, 1997.50)	86.10±12.40	8.00 (6.00, 9.00)	6.20 (5.20, 7.88)
High school/Technical secondary school	74 (32.10)	23.95 (21.95, 25.20)	0.85 (0.83, 0.87)	18.30 (17.33, 20.10)	14.00 (12.00, 16.00)	−10.50 (−13.25, −7.00)	−5.00 (−6.00, −4.00)	1905 (1767.5, 2102.50)	90.70±13.49	8.00 (5.00, 9.25)	6.65 (4.90, 8.40)
College or above	28 (12.20)	23.80 (21.30, 25.10)	0.85 (0.82, 0.88)	18.25 (17.10, 20.68)	14.00 (12.00, 16.00)	−9.00 (−10.00, −2.00)	−3.50 (−5.00, −1.50)	2045 (1887.5, 2175)	96.39±12.39	5.00 (3.00, 7.00)	8.25 (6.90, 10.30)
Test statistic		0.924[b]	1.468[b]	1.298[b]	6.916[b]	25.816[b]	30.398[b]	20.174[b]	5.884[d]	27.401[b]	25.394[b]
P		0.82	0.69	0.73	0.075	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Monthly household income (Yuan)											
<1000	4 (1.70)	21.10 (18.58, 24.08)	0.82 (0.79, 0.86)	15.55 (14.20, 19.30)	9.00 (6.75, 12.00)	−16.50 (−18.75, −13.50)	−7.00 (−8.75, −6.00)	1570 (1465, 1757.5)	71.25±21.38	15.00 (12.75, 18.00)	2.75 (2.20, 3.30)
1000–2999	51 (22.20)	24.20 (21.70, 25.20)	0.85 (0.83, 0.88)	18.30 (17.10, 19.90)	13.00 (11.00, 15.00)	−11.00 (−15.00, −8.00)	−6.00 (−7.00, −5.00)	1850 (1740, 1980)	83.88±11.86	8.00 (6.00, 11.00)	6.10 (4.30, 8.20)
3000–4999	99 (43.10)	23.40 (21.30, 25.20)	0.85 (0.82, 0.88)	18.10 (16.90, 20.80)	13.00 (11.00, 16.00)	−11.00 (−14.00, −8.00)	−5.00 (−6.00, −4.00)	1890 (1720, 2050)	89.97±13.45	8.00 (6.00, 9.00)	6.50 (5.00, 7.90)
≥5000	76 (33.00)	23.95 (22.03, 25.28)	0.85 (0.83, 0.88)	18.15 (17.00, 20.10)	13.50 (12.00, 15.75)	−10.00 (−12.00, −6.25)	−5.00 (−6.00, −3.50)	1905 (1782.5, 2125)	91.46±11.80	7.00 (5.00, 9.00)	6.85 (5.50, 9.08)
Test statistic		2.843[b]	2.884[b]	3.634[b]	6.237[b]	14.401[b]	20.114[b]	12.187[b]	6, 446[d]	17.683[b]	15.942[b]
P		0.417	0.41	0.304	0.101	0.002	<0.001	0.007	<0.001	0.001	0.001
Comorbid chronic diseases											
No	105 (45.07)	23.80 (21.40, 25.20)	0.85 (0.83, 0.88)	18.10 (17.00, 21.05)	13.00 (11.50, 15.50)	−9.00 (−12.00, −7.00)	−5.00 (−6.00, −3.00)	1950 (1790, 2105)	92.27±12.90	6.00 (4.00, 8.00)	7.80 (6.00, 9.30)
Yes	125 (54.30)	23.90 (21.60, 25.15)	0.85 (0.83, 0.87)	18.20 (16.90, 20.10)	13.00 (11.00, 16.00)	−12.00 (−15.00, −9.00)	−6.00 (−6.00, −5.00)	1810 (1700, 1970)	85.86±12.72	9.00 (7.50, 11.00)	5.60 (4.20, 6.90)
Test statistic		−0.289[a]	−0.311[a]	−0.076[a]	−0.677[a]	−4.458[a]	−4.708[a]	−3.694[a]	3.778[c]	−7.135[a]	−6.735[a]
P		0.773	0.755	0.94	0.498	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

(*Continued*)

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Table 1 (Continued).

Variables	n (%)	BMI [kg/m^2, M (P25, P75)]	WHR [M (P25, P75)]	Handgrip Strength [kg, M (P25, P75)]	30-Second Chair Stand Text [number, M (P25, P75)]	Back Scratch Test [cm, M (P25, P75)]	Chair Sit-and-Reach Test [cm, M (P25, P75)]	Forced Vital Capacity [mL, M (P25, P75)]	2-Minute Step Test [step, (Mean ±SD)]	Load Distribution Difference Between Both Feet [%, M (P25, P75)]	One-Leg Stance Test with Eyes Closed [s, M (P25, P75)]
Tumor stage											
I	34 (14.80)	23.25 (21.30, 24.65)	0.84 (0.82, 0.87)	18.30 (17.73, 20.35)	13.00 (11.00, 16.00)	−11.50 (−14.25, −6.75)	−5.00 (−6.25, −3.75)	1870 (1772, 2102.5)	91.41±15.04	8.00 (5.00, 9.00)	6.15 (4.90, 8.45)
II	150 (65.20)	24.10 (21.78, 25.23)	0.85 (0.83, 0.88)	18.15 (17.00, 20.23)	13.00 (11.75, 16.00)	−10.00 (−13.00, −8.00)	−5.00 (−6.00, −4.00)	1880 (1740, 2030)	88.44±12.64	8.00 (5.00, 9.00)	6.80 (5.18, 8.23)
III	46 (20.00)	23.10 (21.20, 24.90)	0.84 (0.82, 0.87)	17.95 (16.50, 19.80)	13.00 (10.00, 16.00)	−12.00 (−15.00, −9.00)	−6.00 (−6.25, −4.00)	1885 (1727.5, 2035)	87.98±13.47	9.00 (6.00, 10.00)	6.00 (4.70, 7.23)
Test statistic		3.923[b]	5.289[b]	1.883[b]	0.978[b]	5.748[b]	2.332[b]	0.488[b]	0.813[d]	3.347[b]	3.073[b]
P		0.141	0.071	0.39	0.613	0.056	0.312	0.784	0.445	0.188	0.215
Chemotherapy regimen											
AC	10 (4.30)	22.35 (21.28, 23.60)	0.83 (0.82, 0.84)	19.60 (18.23, 21.83)	15.00 (12.75, 18.00)	−6.50 (−11.25, −3.75)	−4.50 (−5.25, −2.25)	1955 (1850, 2400)	91.30±16.95	7.50 (3.00, 8.00)	7.00 (5.98, 9.68)
AC-T	113 (49.10)	23.70 (21.25, 25.20)	0.85 (0.82, 0.88)	18.00 (16.55, 20.10)	13.00 (11.00, 16.00)	−11.00 (−13.50, −8.00)	−5.00 (−6.00, −4.00)	1840 (1715, 2015)	86.63±12.30	8.00 (5.00, 9.00)	6.70 (5.20, 8.40)
TC	31 (13.50)	24.50 (22.10, 25.20)	0.86 (0.83, 0.88)	18.30 (17.50, 20.10)	14.00 (12.00, 15.00)	−11.00 (−14.00, −8.00)	−5.00 (−6.00, −3.00)	1970 (1810, 2260)	99.13±12.20	9.00 (5.00, 11.00)	6.00 (3.50, 8.00)
TCb	12 (5.20)	24.15 (21.90, 25.10)	0.86 (0.83, 0.87)	19.65 (18.10, 21.43)	14.50 (13.00, 16.75)	−11.50 (−14.75, −8.50)	−5.50 (−6.00, −4.25)	2005 (1822.5, 2120)	96.08±15.58	9.50 (8.25, 11.00)	4.65 (3.93, 6.00)
AT	22 (9.60)	22.70 (19.40, 24.45)	0.84 (0.81, 0.86)	17.45 (16.43, 19.95)	12.00 (10.00, 14.50)	−12.00 (−14.50, −8.75)	−5.50 (−6.00, −4.00)	1745 (1607.5, 2000)	83.45±11.58	8.00 (6.75, 9.00)	6.40 (5.18, 6.90)
AC-TH	42 (18.30)	24.30 (23.03, 25.35)	0.86 (0.84, 0.89)	18.10 (17.18, 19.85)	13.00 (11.75, 15.00)	−11.00 (−13.25, −9.00)	−6.00 (−6.00, −4.00)	1850 (1750, 2002.5)	87.07±10.98	7.50 (5.00, 9.00)	6.85 (5.15, 8.45)
Test statistic		10.861[b]	12.505[b]	11.213[b]	9.431[b]	9.351[b]	5.585[b]	20.063[b]	6.891[d]	10.812[b]	15.482[b]
P		0.054	0.028	0.047	0.093	0.096	0.349	0.001	<0.001	0.055	0.008
Hemoglobin levels (g/L)											
<90	43 (18.70)	18.30 (17.20, 23.30)	0.80 (0.79, 0.84)	16.20 (15.10, 17.00)	10.00 (9.00, 11.00)	−12.00 (−14.00, −9.00)	−5.00 (−6.00, −4.00)	1790 (1700, 1890)	85.05±9.69	8.00 (5.00, 9.00)	6.70 (5.20, 8.70)
109–90	76 (33.00)	24.40 (23.23, 25.48)	0.87 (0.84, 0.89)	17.45 (16.90, 18.40)	13.00 (11.00, 14.00)	−12.50 (−15.00, −9.25)	−6.00 (−7.00, −5.00)	1785 (1650, 1910)	84.46±12.55	8.50 (6.25, 10.00)	6.00 (4.70, 7.38)
≥110	111 (48.30)	23.90 (22.10, 25.20)	0.85 (0.83, 0.88)	20.10 (18.30, 22.30)	15.00 (13.00, 17.00)	−9.00 (−12.00, −7.00)	−5.00 (−6.00, −4.00)	2000 (1860, 2150)	93.20±13.40	7.00 (5.00, 9.00)	6.80 (5.10, 8.40)
Test statistic		43.894[b]	49.939[b]	125.026[b]	117.871[b]	25.428[b]	18.447[b]	51.832[b]	13.369[d]	5.305[b]	3.727[b]
P		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.07	0.155
Physical activity levels											
Low	137 (59.60%)	24.50 (22.05, 25.60)	0.87 (0.83, 0.89)	17.20 (16.20, 18.10)	12.00 (10.00, 13.00)	−12.00 (−15.00, −10.00)	−6.00 (−7.00, −5.00)	1790 (1650, 1910)	83.91±11.16	8.00 (6.00, 10.00)	6.10 (4.85, 7.70)
Moderate	73 (31.70%)	23.50 (22.20, 24.30)	0.85 (0.83, 0.86)	20.30 (19.20, 21.80)	16.00 (14.00, 17.00)	−9.00 (−10.00, −8.00)	−5.00 (−6.00, −4.00)	2010 (1860, 2150)	94.49±12.47	7.00 (5.00, 9.00)	6.80 (5.30, 8.40)
High	20 (8.70%)	21.40 (21.20, 21.95)	0.82 (0.81, 0.83)	23.90 (22.98, 24.20)	18.00 (18.00, 19.00)	−7.50 (−11.25, −6.00)	−4.00 (−5.00, −3.25)	2195 (2027.5, 2285)	101.40±12.03	6.50 (5.00, 8.75)	7.60 (5.58, 8.63)
Test statistic		23.433[b]	22.687[b]	154.121[b]	147.238[b]	45.772[b]	27.14[b]	82.096[b]	32.429[d]	5.994[b]	5.963[b]
P		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.05	0.051
Menopausal status											
Premenopausal status	78 (33.90%)	23.20 (21.50, 24.20)	0.84 (0.82, 0.87)	19.30 (17.80, 22.30)	15.00 (13.00, 17.00)	−8.00 (−9.00, −3.75)	−4.00 (−5.00, −2.00)	2085 (1975, 2210)	100.15±9.962	5.00 (3.00, 7.00)	8.40 (6.975, 10.425)
Post-menopausal status	152 (66.10%)	24.25 (21.70, 25.30)	0.86 (0.83, 0.88)	17.90 (16.825, 19.175)	13.00 (11.00, 14.00)	−12.00 (−15.00, −11.00)	−6.00 (−7.00, −5.00)	1790 (1680, 1880)	82.95±10.553	9.00 (7.25., 10.00)	5.50 (4.35, 6.80)
Test statistic		−2.618[a]	−2.439[a]	−4.717[a]	−5.43[a]	−9.867[a]	−9.723[a]	−10.264[a]	11.923[c]	−9.631[a]	−9.297[a]
P		0.009	0.015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BC subtypes											
Luminal A	93 (40.40%)	24.80 (24.10, 25.75)	0.87 (0.86, 0.89)	18.20 (17.20, 19.60)	13.00 (1200, 15.00)	−12.00 (−15.00, −9.00)	−6.00 (−7.00, −5.00)	1820 (1715, 1980)	86.55±12.549	9.00 (7.00, 10.00)	6.00 (4.60, 7.10)
Luminal B	31 (13.50%)	25.30 (24.30, 25.80)	0.89 (0.87, 0.91)	18.1 (16.90, 20.10)	13.00 (12.00, 15.00)	−12.00 (−14.00, −9.00)	−5.00 (−7.00, −4.00)	1850 (1710, 1980)	88.55±11.781	8.00 (5.00, 9.00)	6.30 (5.50, 8.50)
HER2-enriched	66 (28.70%)	21.65 (19.025, 23.225)	0.83 (0.80, 0.84)	18.05 (16.425, 20.35)	13.00 (10.00, 16.00)	−10.00 (−12.00, −8.00)	−5.00 (−6.00, −4.00)	1900 (1747.5, 2040)	87.89±13.983	8.00 (5.00, 9.00)	6.85 (5.20, 8.325)
TNBC	40 (17.40%)	21.30 (18.825, 23.05)	0.82 (0.80, 0.84)	18.30 (16.525, 22.25)	13.50 (11.00, 17.00)	−8.50 (−12.00, −4.00)	−4.00 (−5.75, −2.25)	2025 (1847.5, 2180)	95.65±12.234	6.00 (3.00, 8.00)	8.00 (6.125, 9.175)
Test statistic		125.278[b]	132.744[b]	1.477[b]	2.374[b]	13.453[b]	21.301[b]	14.253[b]	4.856[d]	16.384[b]	15.448[b]
P		<0.001	<0.001	0.688	0.499	0.004	<0.001	0.003	0.03	0.001	0.001

Notes: [a]Z-value; [b]H-value; [c]t-value; [d]F-value.

Abbreviations: BMI, body mass index; WHR, waist-to-hip ratio; AC, Anthracycline + Cyclophosphamide; AC-T, Anthracycline + Cyclophosphamide followed by Taxane; TC, Docetaxel + Cyclophosphamide; TCb, Docetaxel + Carboplatin; AT, Anthracycline + Taxane; AC-TH, Anthracycline + Cyclophosphamide followed by Taxane + Trastuzum; BC, breast cancer; HER2, human epidermal growth factor receptor 2; TNBC, triple negative breast cancer.

difference between both feet and one-leg stance with eyes closed) were significantly influenced by chronic comorbidities, age, educational level, household income, breast cancer subtypes, menopausal status, and chemotherapy regimen ($P<0.05$). Detailed results are presented in Table 1.

Correlation Analysis Between Sedentary Time and HRPF

The median sedentary time among 230 breast cancer patients undergoing chemotherapy was 380 minutes (interquartile range: 250–450) per day. Sedentary behavior was significantly associated with all five dimensions of HRPF, as detailed in Table 2.

Multiple Linear Regression Analysis of Factors Affecting HRPF in Breast Cancer Patients Undergoing Chemotherapy

Inclusion and Coding of Variables for Multiple Linear Regression Analysis of HRPF in Breast Cancer Patients Undergoing Chemotherapy

Multivariate linear regression analysis was conducted to identify factors influencing five dimensions of health-related physical fitness in breast cancer patients undergoing chemotherapy. The five dimensions of physical fitness were used as dependent variables, while sedentary time and variables found to be statistically significant in univariate analysis were entered as independent variables. Continuous variables such as age, hemoglobin level, and sedentary time were included using their original values. Categorical variables were coded as follows: education level (primary school or below=1, middle school=2, high school/technical secondary school=3, college or above=4), monthly household income (<1000 yuan=1, 1000–2999 yuan =2, 3000–4999 yuan =3, ≥5000 yuan=4), comorbid chronic disease (no=0, yes=1), and physical activity level (low=1, moderate=2, high=3). Chemotherapy regimen was included using dummy variables with the AC regimen as the reference group: AC-T (1, 0, 0, 0, 0), TC (0, 1, 0, 0, 0), TCb (0, 0, 1, 0, 0), AT (0, 0, 0, 1, 0), and AC-TH (0, 0, 0, 0, 1). Breast cancer subtypes were coded as dummy variables with Luminal A as the reference: Luminal B (1, 0, 0), HER2-enriche (0, 1, 0), and TNBC (0, 0, 1). The criteria for entry and removal of variables were $\alpha\_in = 0.05$ and $\alpha\_out = 0.10$, respectively.

Analysis of Factors Affecting Body Composition in Breast Cancer Patients Undergoing Chemotherapy

The results indicated that hemoglobin level, breast cancer subtypes, and sedentary time were significant predictors of body composition—specifically BMI and waist-to-hip ratio—among breast cancer patients undergoing chemotherapy ($P < 0.001$). Detailed results are presented in Tables 3 and 4.

Analysis of Factors Influencing Muscular Strength and Endurance Fitness in Breast Cancer Patients Undergoing Chemotherapy

The results indicated that hemoglobin level, menopausal status, and physical activity level were significant predictors of upper limb muscular strength (handgrip strength) in breast cancer patients undergoing chemotherapy ($P < 0.001$). Additionally, age, hemoglobin level, menopausal status, and physical activity level were significantly associated with lower limb muscular strength, as assessed by the 30-second chair stand test ($P < 0.001$). Detailed results are presented in Tables 5 and 6.

Analysis of Factors Influencing Flexibility in Breast Cancer Patients Undergoing Chemotherapy

Multivariate regression analysis revealed that age and physical activity level were independently associated with flexibility-related physical fitness in breast cancer patients during chemotherapy ($P<0.001$), as detailed in Tables 7 and 8.

Table 2 Correlation Analysis Between Sedentary Time and HRPF During Chemotherapy in Breast Cancer Patients (n=230, *r*-Value)

Variables	BMI	WHR	Handgrip Strength	30-Second Chair Stand Text	Back Scratch Test	Chair Sit-and-Reach Test	Forced Vital Capacity	2-Minute Step Test	Load Distribution Difference Between Both Feet	One-Leg Stance Test with Eyes Closed
Sedentary time	0.523**	0.478**	−0.504**	−0.523**	−0.341**	−0.371**	−0.436**	−0.346**	0.143*	−0.177**

Notes: **$P<0.001$,*$P<0.05$.
Abbreviations: BMI, body mass index; WHR, waist-to-hip ratio.

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Table 3 Multiple Linear Regression Analysis of BMI Among Breast Cancer Patients Undergoing Chemotherapy (n = 230)

Variable	B	SE	β	t	P	VIF
Constant	16.778	1.325		12.663	0.000	
Sedentary time	0.004	0.001	0.200	2.954	0.003	2.453
Physical activity level	−0.462	0.310	−0.113	−1.493	0.137	3.083
Hemoglobin level	0.063	0.009	0.403	6.779	0.000	1.902
Menopausal status	0.056	0.257	0.010	0.217	0.828	1.123
Breast cancer subtypes						
Luminal B	0.306	0.364	0.039	0.841	0.401	1.171
HER2-enriche	−2.750	0.311	−0.468	−8.847	0.000	1.502
TNBC	−2.890	0.362	−0.412	−7.980	0.000	1.431

Notes: R^2 = 0.587, Adjusted R^2 =0.574, F=45.092, *P*<0.001.
Abbreviations: HER2, human epidermal growth factor receptor 2; TNBC, triple negative breast cancer.

Table 4 Multiple Linear Regression Analysis of Waist-to-Hip Ratio (WHR) Among Breast Cancer Patients Undergoing Chemotherapy (n = 230)

Variable	B	SE	β	t	P	VIF
Constant	0.758	0.016		47.444	0.000	
HER2-enriche	−0.038	0.004	−0.451	−9.109	0.000	1.445
TNBC	−0.040	0.005	−0.395	−8.275	0.000	1.347
Sedentary time	0.000	0.000	0.360	7.031	0.000	1.551
Hemoglobin level	0.001	0.000	0.304	6.282	0.000	1.387
Luminal B	0.011	0.005	0.100	2.267	0.024	1.160

Notes: R^2 =0.621, Adjusted R^2 =0.612, F =73.316, *P*<0.001.
Abbreviations: HER2, human epidermal growth factor receptor 2; TNBC, triple negative breast cancer.

Table 5 Multiple Linear Regression Analysis of Handgrip Strength During Chemotherapy in Breast Cancer Patients (n = 230)

Variable	B	SE	β	t	P	VIF
Constant	10.099	0.572		17.660	0.000	
Physical activity level	2.193	0.140	0.562	15.674	0.000	1.652
Hemoglobin level	0.060	0.005	0.402	11.356	0.000	1.613
Menopausal status	−0.696	0.154	−0.130	−4.514	0.000	1.061

Notes: R^2=0.824, Adjusted R^2=0.822, F=353.748, *P*<0.001.

Table 6 Multiple Linear Regression Analysis of 30-Second Chair Stand Test During Chemotherapy in Breast Cancer Patients (n = 230)

Variable	B	SE	β	t	P	VIF
Constant	6.000	0.807		7.431	0.000	
Sedentary time	0.000	0.001	−0.002	−0.046	0.964	2.271
Physical activity level	2.594	0.213	0.577	12.200	0.000	3.358
Hemoglobin level	0.075	0.006	0.438	13.237	0.000	1.645
Menopausal status	−0.566	0.239	−0.092	−2.365	0.019	2.245
Age	−0.104	0.012	−0.337	−8.850	0.000	2.174

Notes: R^2=0.851, Adjusted R^2=0.847, F=254.985, *P*<0.001.

Table 7 Multiple Linear Regression Analysis of Back Scratch Test Among Breast Cancer Patients Undergoing Chemotherapy (n = 230)

Variable	B	SE	β	t	P	VIF
Constant	0.723	2.444		0.296	0.767	
Sedentary time	−0.001	0.002	−0.029	−0.491	0.624	2.536
Physical activity level	2.836	0.472	0.417	6.015	0.000	3.559
Hemoglobin level	0.001	0.014	0.003	0.048	0.961	2.025
Menopausal status	−0.663	0.525	−0.071	−1.263	0.208	2.334
Age	−0.291	0.028	−0.623	−10.507	0.000	2.594
Comorbid chronic diseases	−0.427	0.373	−0.048	−1.145	0.254	1.304
Education level	0.350	0.206	0.071	1.699	0.091	1.279
Monthly household income	0.234	0.220	0.041	1.060	0.291	1.131
Breast cancer subtypes						
Luminal B	−0.240	0.519	−0.019	−0.462	0.644	1.188
HER2-enriche	0.131	0.442	0.013	0.295	0.768	1.512
TNBC	0.121	0.521	0.010	0.232	0.817	1.470

Notes: R^2=0.705, Adjusted R^2=0.69, F=47.357, *P*<0.001.
Abbreviations: HER2, human epidermal growth factor receptor 2; TNBC, triple negative breast cancer.

Table 8 Multiple Linear Regression Analysis of Chair Sit-and-Reach Test During Chemotherapy in Breast Cancer Patients (n = 230)

Variable	B	SE	β	t	P	VIF
Constant	0.999	1.220		0.819	0.414	
Sedentary time	−0.002	0.001	−0.106	−1.637	0.103	2.536
Physical activity level	0.928	0.235	0.301	3.941	0.000	3.559
Hemoglobin level	−0.003	0.007	−0.026	−0.456	0.649	2.025
Menopausal status	−0.080	0.262	−0.019	−0.303	0.762	2.334
Age	−0.137	0.014	−0.646	−9.906	0.000	2.594
Comorbid chronic diseases	−0.116	0.186	−0.029	−0.624	0.533	1.304
Education level	0.128	0.103	0.057	1.247	0.214	1.279
Monthly household income	0.204	0.110	0.080	1.852	0.065	1.131
Breast cancer subtypes						
Luminal B	−0.014	0.259	−0.002	−0.054	0.957	1.188
HER2-enriche	0.065	0.221	0.015	0.294	0.769	1.512
TNBC	0.238	0.260	0.045	0.916	0.361	1.470

Notes: R^2=0.642, Adjusted R^2=0.624, F=35.567, *P*<0.001.
Abbreviations: HER2, human epidermal growth factor receptor 2; TNBC, triple negative breast cancer.

Analysis of Factors Affecting Cardiorespiratory Fitness in Breast Cancer Patients Undergoing Chemotherapy

The results indicated that four variables—age, physical activity level, hemoglobin concentration, and chemotherapy regimen (with the TC and TCb regimen associated with increased vital capacity compared to the reference AC regimen)—were significant predictors of forced vital capacity among breast cancer patients undergoing chemotherapy (*P*<0.001). Similarly, three variables—age, physical activity level, and chemotherapy regimen (with the TC and TCb regimens associated with higher performance on the 2-minute step test compared to the AC regimen)—were significantly associated with 2-minute step test outcomes (*P*<0.001). Detailed findings are presented in Tables 9 and 10.

Analysis of Factors Affecting Balance-Related Fitness in Breast Cancer Patients Undergoing Chemotherapy

The results indicated that age, chemotherapy regimen (with the AC regimen as the reference, the TCb and TC regimen was associated with reduced balance performance), sedentary time, and comorbid chronic conditions were significant predictors of balance-related fitness—including load distribution difference between both feet and one-leg stance test with eyes closed—among breast cancer patients undergoing chemotherapy (P < 0.001). For detailed results, see Tables 11 and 12.

Table 9 Multiple Linear Regression Analysis of Forced Vital Capacity Among Breast Cancer Patients During Chemotherapy (n = 230)

Variable	B	SE	*β*	t	*P*	VIF
Constant	2262.484	45.638		49.574	0.000	
Physical activity level	208.298	9.878	0.601	21.088	0.000	1.658
Age	−15.961	0.534	−0.669	−29.865	0.000	1.025
TC	156.637	14.838	0.237	10.557	0.000	1.029
Hemoglobin level	1.333	0.379	0.100	3.517	0.001	1.668
TCb	70.140	22.725	0.069	3.086	0.002	1.024

Notes: R^2=0.89, Adjusted R^2=0.88, F=363.725, *P*<0.001.
Abbreviations: TC, Docetaxel + Cyclophosphamide; TCb, Docetaxel + Carboplatin.

Table 10 Multiple Linear Regression Analysis of the 2-minute Step Test Among Breast Cancer Patients During Chemotherapy (n=230)

Variable	B	SE	*β*	t	*P*	VIF
Constant	119.862	2.523		47.501	0.000	
Physical activity level	10.510	0.655	0.521	16.046	0.000	1.018
Age	−0.923	0.045	−0.665	−20.535	0.000	1.012
TC	12.053	1.243	0.313	9.694	0.000	1.009
TCb	8.669	1.919	0.147	4.517	0.000	1.019

Notes: R^2=0.767, Adjusted R^2=0.763, F=185.2556, *P*<0.001.
Abbreviations: TC, Docetaxel + Cyclophosphamide; TCb, Docetaxel + Carboplatin.

Table 11 Multiple Linear Regression Analysis of Load Distribution Difference Between Both Feet Among Breast Cancer Patients During Chemotherapy (n=230)

Variable	B	SE	*β*	t	*P*	VIF
Constant	−8.576	0.698		−12.285	0.000	
Age	0.266	0.013	0.780	21.294	0.000	1.217
Sedentary time	0.005	0.001	0.188	5.612	0.000	1.012
TCb	2.103	0.487	0.145	4.318	0.000	1.585
Comorbid chronic diseases	0.711	0.238	0.110	2.992	0.003	1.219
TC	0.768	0.315	0.081	2.433	0.016	1.010

Notes: R^2=0.753, Adjusted R^2=0.747, F=136.510, *P*<0.001.
Abbreviations: TC, Docetaxel + Cyclophosphamide; TCb, Docetaxel + Carboplatin.

Table 12 Multiple Linear Regression Analysis of One-Leg Stance Test with Eyes Closed Among Breast Cancer Patients During Chemotherapy (n=230)

Variable	B	SE	*β*	t	*P*	VIF
Constant	18.417	0.449		41.025	0.000	
Age	−0.189	0.008	−0.790	−23.545	0.000	1.217
Sedentary time	−0.004	0.001	−0.214	−6.987	0.000	1.012
TCb	−1.731	0.313	−0.170	−5.527	0.000	1.020
TC	−1.060	0.203	−0.160	−5.224	0.000	1.010
Comorbid chronic diseases	−0.461	0.153	−0.101	−3.018	0.003	1.219

Notes: R^2=0.793, Adjusted R^2=0.788, F=171.723, *P*<0.001.
Abbreviations: TC, Docetaxel + Cyclophosphamide; TCb, Docetaxel + Carboplatin.

Discussion

Analysis of HRPF Status During Chemotherapy in Breast Cancer Patients

This study measured five dimensions of HRPF in 230 breast cancer patients undergoing chemotherapy. The results showed that the median BMI was 23.8 kg/m^2, which is at the upper limit of the normal range. The median waist-to-hip ratio was 0.85, approaching the threshold for abdominal obesity in women (>0.85),[26] indicating abnormal fat distribution, particularly an increased risk of visceral fat accumulation in these patients. The median grip strength was 18.15 kg, which is close to the threshold for low grip strength in women (<18 kg),[27] reflecting a notable decline in muscular strength. The median age of breast cancer patients in this study was 54 years. According to the National Physical Fitness Standards (2023 revision),[28] the median lung capacity only met the minimum standard, while the median values for seated forward flexion and eyes-closed single-leg standing did not meet the standard.

In summary, the five dimensions of HRPF in the study participants were generally below normal standards or near threshold levels. The reasons for this may include: (1) Chemotherapy drugs is associated with fat metabolism,[29] increase inflammatory responses, cause metabolic abnormalities, leading to muscle mass loss,[30] and result in side effects such as cardiac toxicity and neurotoxicity;[31,32] (2) The traditional Chinese concept of "resting" leads to insufficient physical activity in patients, exacerbating the decline in HRPF levels. Additionally, cardiac toxicity during chemotherapy may increase patients' fear of exercise. Studies have shown that patients often cannot distinguish between the physiological cardiac and pulmonary responses caused by exercise and the pathological symptoms of cardiopulmonary discomfort,[33] which exacerbates exercise-related fear and avoidance, further reducing HRPF levels.

A recent study assessed HRPF in breast cancer patients, and its findings align with those of the present study,[34] underscoring the importance of early HRPF evaluation for improving quality of life. However, notable differences exist between the two studies. Ki-Yong An et al focused on newly diagnosed patients, whereas our study evaluated HRPF during chemotherapy, thus capturing the impact of treatment on physical fitness. Moreover, Ki-Yong An et al primarily investigated the relationship between HRPF and patient-reported symptoms, while the primary aim of our study was to identify early risk factors for HRPF and provide a basis for personalized exercise intervention programs.

Therefore, exercise rehabilitation programs should be designed based on HRPF assessments, with individualized and staged plans that precisely control exercise intensity according to patients' tolerance, providing multidimensional support to improve exercise adherence, avoid exercise-related fear, and ultimately enhance HRPF during chemotherapy in breast cancer patients.

Factors Affecting HRPF During Chemotherapy in Breast Cancer Patients

Analysis of Factors Affecting Body Composition During Chemotherapy in Breast Cancer Patients

The results indicate that patients with lower hemoglobin levels, higher physical activity, and shorter sedentary time exhibit lower body composition indices, including BMI and waist-to-hip ratio. Compared with the Luminal A subtype, patients with TNBC and HER2-enriched subtypes showed reduced BMI and waist-to-hip ratios. This study also identified a positive correlation between BMI, hemoglobin levels, and waist-to-hip ratio, consistent with the findings of Auvinen et al.[35] This association may be attributable to metabolic changes driven by lower hemoglobin levels. Furthermore, Jin Jiahui et al reported that individuals with lower physical activity levels had significantly higher body fat percentages and waist-to-hip ratios compared to those with higher activity levels.[36] Reducing sedentary time promotes more daily activities, such as walking and standing, which help maintain a negative energy balance and limit fat accumulation. Our study found that each additional minute of sedentary behavior was associated with a slight increase in BMI (0.004) and waist-to-hip ratio. This may be attributable to the measurement of sedentary time in minutes; in our cohort, the median daily sedentary time was 380 minutes, and the cumulative duration could meaningfully impact BMI. Consistent with our findings, an observational study reported higher BMI in patients with Luminal breast cancer, while TNBC and HER2-enriched subtypes exhibited lower BMI.[37] Nonetheless, some studies have reported contrasting results, and the underlying mechanisms remain unclear. One potential explanation is that high BMI is a recognized risk factor for Luminal breast cancer.[38] These findings highlight the need for further research to elucidate the relationship between breast cancer subtypes and body composition.

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Therefore, clinical healthcare providers should pay particular attention to patients with low hemoglobin levels, correcting anemia promptly, increasing physical activity, and ensuring early identification of luminal-type breast cancer. For patients with normal hemoglobin levels, multi-channel health education should be provided to encourage participation in diverse physical activities and short bouts of exercise, thereby supporting the maintenance of healthy body composition during chemotherapy.

Analysis of Factors Affecting Muscular Strength and Endurance During Chemotherapy in Breast Cancer Patients

Higher hemoglobin levels, Premenopausal status, and higher levels of physical activity levels are associated with greater upper limb muscular strength in patients, while younger age, higher hemoglobin levels, Premenopausal status, and higher physical activity levels are associated with greater lower limb muscular strength. Muscle contraction and strength output require a significant amount of energy, which is dependent on oxygen supply. Therefore, the quantity and quality of hemoglobin directly impact the oxygen delivery to muscles, thereby influencing both muscular strength and endurance. Hammer et al found a positive correlation between hemoglobin levels and grip strength in women under 80 years of age.[39] Regular physical activity promotes the synthesis of muscle proteins, facilitating muscle growth and recovery, and thus enhancing muscle fitness. A study by Pan Liang et al found that physical activity levels are inversely related to the risk of muscle mass loss.[40] A study has shown that patients undergoing aromatase inhibitor therapy experience a higher prevalence of sarcopenia.[41] Our findings indicate that postmenopausal women exhibit a decline in both upper and lower limb strength compared to their premenopausal counterparts. In addition to age, the predominant use of aromatase inhibitors in postmenopausal hormone therapy was identified as a key factor contributing to this decline. Although the study observed a modest reduction in upper limb strength (0.69 kg) and lower limb strength (0.56 kg) in postmenopausal women compared to premenopausal women, these findings underscore the importance of longitudinal studies to assess whether prolonged use of these medications exacerbates muscle strength deterioration over time.

As age increases, the number and function of muscle stem cells (MuSCs) and fibro-adipogenic progenitors (FAPs) undergo significant changes, which affect the muscle regeneration capacity.[42] In this study, age was not found to be an influencing factor for upper limb strength, likely due to the fact that breast cancer patients undergoing chemotherapy tend to focus on functional upper limb training, which may have introduced a bias related to age.

Analysis of Factors Affecting Flexibility in Breast Cancer Patients During Chemotherapy

The study found that younger age and higher physical activity levels are associated with better flexibility in breast cancer patients undergoing chemotherapy. As age increases, the body's flexibility tends to decline, primarily due to the reduced elasticity of muscles, tendons, and ligaments. Research has shown that for individuals aged 55 to 86 years, flexibility in the shoulder and hip joints decreases by an average of 5 to 6 degrees every decade.[43] Additionally, physical activity levels are positively correlated with flexibility. A study of healthy young individuals found that those with higher physical activity levels exhibited a greater range of motion in hip flexion tests and better lower limb flexibility.[44]

Therefore, for older breast cancer patients undergoing chemotherapy, it is recommended to increase their physical activity levels to help delay and improve the decline in flexibility, ultimately enhancing their overall health and physical fitness.

Analysis of Factors Affecting Cardiorespiratory Fitness in Breast Cancer Patients During Chemotherapy

The study found that younger age, higher physical activity levels, and higher hemoglobin levels are associated with better cardiopulmonary endurance in breast cancer patients undergoing chemotherapy. Chemotherapy regimens can also impact patients' cardiopulmonary endurance. Research has shown that cardiopulmonary function decreases by approximately 3% per year as individuals age in adulthood.[45] Physical activity can increase the heart's blood pumping volume, improving the heart's effective pumping efficiency, thereby enhancing cardiopulmonary function. Additionally, physical activity strengthens respiratory muscles, such as the intercostal muscles and diaphragm, which in turn increases lung capacity, allowing for a greater exhalation of air after maximal inhalation. A study by Song Yuxin found that higher physical activity levels lead to better cardiopulmonary endurance in older adults.[46] Furthermore, studies indicate that chemotherapy regimens involving anthracyclines, known for their cardiotoxicity, lead to a progressive decline in cardiopulmonary function,[47] which aligns with the findings of this study.

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This study found that with each additional year of age, Forced Vital Capacity decreases by approximately 15 mL. While this effect is statistically significant, its clinical relevance is limited. Future longitudinal studies are needed to clarify the relationship between age and lung function in breast cancer patients undergoing chemotherapy. Such research is of critical clinical importance for understanding the impact on rehabilitation outcomes and overall quality of life in this population. In addition, this study demonstrated that hemoglobin levels were statistically significant only for Forced Vital Capacity and not for the 2-minute step test. One possible explanation is that hemoglobin influences gas exchange, whereas the 2-minute step test is influenced by subjective perception, with the pace being adjusted by the participant. As a result, oxygen uptake may not reach maximal levels, reducing the dependence on hemoglobin levels. Additionally, patients with severe anemia were excluded from the study, and a review of the data revealed that the number of participants with mild anemia was higher than those with moderate anemia, suggesting that selection bias may have contributed to this finding. Future studies should rigorously control for confounding variables to further explore the relationship between hemoglobin levels and performance on the 2-minute step test. In our study, only the TC and TCb chemotherapy regimens were significantly associated with step test performance compared with the AC regimen, showing mean differences of 12 and 8 steps, respectively. The subgroup sizes were 31 (13.5%) for TC and 12 (5.2%) for TCb. Although these subgroup sample sizes were relatively small, the observed differences indicate a potential influence of chemotherapy regimen on short-term functional capacity. Notably, previous studies conducted in rehabilitation settings have suggested that an improvement of approximately 8 steps in the 2-minute step test represents a clinically meaningful change in lower-limb endurance and functional mobility.[48] Therefore, the differences observed in our study may have practical implications for functional assessment and for developing individualized exercise rehabilitation programs in patients undergoing chemotherapy.

Therefore, healthcare professionals should pay special attention to older patients using anthracycline-based chemotherapy regimens, as their heart function may be more vulnerable. Regular physical exercise should be emphasized to improve cardiopulmonary endurance and mitigate the negative effects on heart and lung function.

Analysis of Factors Affecting Balance-Related Fitness in Breast Cancer Patients During Chemotherapy

The study found that in breast cancer patients undergoing chemotherapy, those who were older, used taxane-based chemotherapy drugs, had longer sedentary time, and had a history of other chronic diseases had significantly worse balance ability. As age increases, the accelerated loss of muscle mass and bone calcium, joint degeneration, and slower nerve conduction lead to a decline in balance ability. Additionally, chronic conditions such as hypertension, diabetes, and stroke can also significantly reduce balance function. Taxane-based chemotherapy drugs commonly cause peripheral neuropathy, which can impair balance function.[49] Prolonged sedentary behavior is an important factor contributing to muscle and bone loss, reducing the body's ability to control balance and negatively affecting static balance ability.[50] In contrast to previous studies, this research did not find a significant correlation between physical activity levels and balance ability. Upon further analysis, it was found that most of the physical activity among the samples was based on daily living activities, and there was a lack of targeted balance training programs. This may explain the inconsistency with prior findings.

Therefore, it is recommended that a systematic and targeted balance training program be developed for high-risk groups, particularly older patients using taxane chemotherapy drugs, to improve their balance ability and prevent falls and related complications.

Conclusion

The results of this study indicate that the overall HRPF levels of breast cancer patients undergoing chemotherapy need to be improved. These levels are influenced by various factors, including age, physical activity level, sedentary time, hemoglobin levels, breast cancer subtypes, menopausal status, and chemotherapy regimen. Based on our findings, healthcare providers should consider incorporating personalized exercise rehabilitation programs tailored to individual factors such as age, hemoglobin levels, treatment regimen, and physical activity status. Early screening of HRPF can help identify patients at higher risk of functional decline, allowing for timely, individualized interventions to maintain or improve physical function during chemotherapy.

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However, this study has certain limitations. The observational design of the study means that only associations, not causal relationships, can be inferred. Additionally, potential measurement biases due to self-reported physical activity and reliance on proxy measures for balance assessment should be explicitly acknowledged. Future research should focus on multi-center, large-scale studies to provide a more comprehensive understanding of the current status and influencing factors of HRPF in breast cancer patients undergoing chemotherapy. Moreover, it is recommended that future studies incorporate objective activity monitoring, specifically designed dynamic balance assessment, and explore a more diverse patient population across multiple centers. This will help provide a more robust theoretical foundation for developing precise and scientifically grounded exercise rehabilitation programs for these patients.

Data Sharing Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Bengbu Medical University (Approval No. [2022]102). All participants provided written informed consent prior to enrollment in the study.

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Disclosure

The authors declare that they have no conflicts of interest in relation to this work.

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