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Original Article

Physiotherapy Section

Effectiveness of Tai Chi Exercise on VO_2max in Patients with Cancer after Chemotherapy: An Experimental Study

SEEMA DAS[1], SOMYATA C SATPATHY SARMA[2], SUBARNA SANKAR DAS[3], TRISHNA KAKATI[4]

ABSTRACT

Introduction: Tai Chi, originally a Chinese martial art, is now recognised as an effective form of aerobic exercise beneficial for cardiac rehabilitation and mental well-being. It involves gentle movements, deep breathing, and relaxation, promoting body awareness and focus. Classified as a moderate-intensity exercise (2.6-6.5 MET), Tai Chi has shown clinical benefits, particularly for individuals with chronic conditions.

Aim: This study aimed to evaluate the effectiveness of Tai Chi exercises by comparing baseline and post-exercise VO_2max scores in cancer patients after chemotherapy.

Materials and Methods: A quasi-experimental study commenced in March 2022 and was completed in September 2022, affiliated with the College of Physiotherapy and Medical Sciences under Srimanta Sankaradeva University of Health Sciences, Guwahati, Assam, India. A total of 30 subjects were assessed, of whom sevenwere excluded, two declined, and 21 participated. After seven dropouts, 15 participants (aged 20-60 years, diagnosed with breast, stomach, or colorectal cancer) at stage II who had completed all doses of chemotherapy completed a 6-week Tai Chi programme (30-minute sessions twice a week). VO_2max was measured pre- and post-intervention. Demographic data (gender, height, weight, cancer type, chemotherapy doses, and vital signs) were considered. SPSS software version 25 was used, the Shapiro-Wilk test for normality was applied, and a paired t-test was conducted for parametric analysis, with statistical significance set at $p<0.05$, where $p<0.001$ was considered highly significant.

Results: Fifteen post-chemotherapy patients participated in a 6-week Tai Chi programme. Pre- and post-programme VO_2max values were analysed using paired sample t-tests, with the Shapiro-Wilk test for normality. The sample consisted of 33% males and 67% females, with a mean age of 42.8 years (SD=8.41). VO_2max increased from a pre-exercise mean of 32.92 to a post-exercise mean of 36.64. Statistical analysis in SPSS version 25 showed significant improvement ($p<0.001$).

Conclusion: The study indicates that a 6-week Tai Chi exercise programme significantly improves VO_2max in cancer patients post-chemotherapy, suggesting its potential as an effective rehabilitative intervention for enhancing cardiovascular fitness and overall well-being in this population.

Keywords: Adjuvant, Cardiorespiratory fitness, Chinese martial art, Neoplasms

INTRODUCTION

Cancer, derived from the Greek word "karkinos," is the second leading cause of death globally, following cardiovascular diseases. It is believed to result from the gradual accumulation of mutations in cancer-related genes [1,2]. Chemotherapy is a cancer treatment method that employs drugs to destroy cancer cells. A chemotherapy cycle involves multiple medications, often administered intravenously through continuous infusion. These infusions can last from 30 minutes to several hours [3]. Cancer treatment has proven effects on survival, but it can be invasive and toxic, leading to various long-term health issues. These may include decreased physical functioning, diminished quality of life, persistent fatigue, and reduced Cardiorespiratory Fitness (CRF) [4]. The most common pulmonary injuries caused by chemotherapy include acute chemotherapy pneumonitis, which is occasionally observed with drugs like Taxane (paclitaxel) and Mitoxantrone. Depending on the medication, early and late pneumonitis may occur with Methotrexate, Bleomycin, and Carmustine. Pulmonary oedema is also associated with Bleomycin when used with supplemental oxygen, and pulmonary fibrosis can be caused by bleomycin, cyclophosphamide, isophosphamide, and Mitomycin-C [5]. Cancer-related fatigue is a frequent symptom among cancer patients, affecting about 50%-70% at the time of diagnosis. Its prevalence rises to 80%-96% in patients undergoing chemotherapy and to 60%-93% in those receiving radiotherapy. CRF is a significant and independent predictor of reduced overall patient satisfaction and diminished quality of life related to health [6]. The mechanisms behind CRF include serotonin imbalance, dysfunction of the Hypothalamic-Pituitary-Adrenal (HPA) axis, alterations in 5-HT receptors, disruption of circadian rhythm, and activation of vagal afferent nerves [7]. VO_2max represents the maximum functional capacity of the cardiorespiratory systems and is considered the most accurate measure of maximal aerobic performance. The absolute VO_2max is one of the key indicators of an individual's CRF in delivering oxygen to active muscles [8]. CRF is measured through maximal oxygen uptake (VO_2max). A sufficient VO_2max is associated with reduced toxic effects of radiotherapy, chemotherapy, and endocrine therapy on the cardiovascular system, respiratory system, and skeletal muscles [4]. Physical Activity (PA) is recommended as a strategy both during and after adjuvant therapy to help manage treatment-related symptoms, reduce early and late comorbidities, and improve quality of life [4]. Tai Chi, a traditional Chinese exercise for health promotion, was first scientifically documented in 1981. It consists of low to moderate-intensity physical activities. Research indicates that Tai Chi positively impacts chronic heart failure, enhances lung function and activity tolerance in patients with chronic obstructive pulmonary disease, and improves balance while reducing falls in older adults. Additionally, it has been shown to boost mental health, alleviate geriatric depression, decrease anxiety, and enhance self-efficacy [6]. Today, the health benefits of Tai Chi are widely recognised, particularly in addressing various mortality and morbidity factors linked to lifestyle-related non-communicable diseases and conditions, such as osteoarthritis, heart disease, cognitive decline, dementia, chronic obstructive pulmonary disease, and stroke, as observed in the 21st century [9]. The five primary styles of Tai Chi are Chen, Yang, Hao, Wu, and Sun. Each style possesses distinct characteristics, including

the integration of mind and body, fluidity of movement, controlled breathing, and focussed mental concentration [10]. The Yang style, renowned for its health benefits, meditation, and self-defence, is the most popular form of Tai Chi globally. It was first developed by Yang Lu Chan in the early 1800s [11].

Cancer and its treatment cause a peripheral release of neuroactive agents that activate the vagal afferent nerve, leading to suppression of somatic muscle activity and induction of sickness behaviour [7], which in turn leads to a reduction in Physical Activity (PA) and CRF. Measurement of VO_2max is generally considered the best indicator of cardiovascular fitness. Studies have reported that VO_2max is a key predictor of longevity. In general, cancer patients exhibit marked and significantly impaired cardiopulmonary functions during and after chemotherapy. Tai Chi seems to be a good choice for improving CRF in coronary disease [12-14]. However, the effect of Tai Chi has not been tested on VO_2max in patients with cancer after chemotherapy. Thus, this present study aims to assess the effectiveness of Tai Chi exercise on VO_2max in the cancer population after chemotherapy.

The study's aim was to compare the VO_2max scores of cancer patients before and after chemotherapy in order to determine the efficacy of Tai Chi workouts.

Null Hypothesis (Ho): There is no significant difference between pre-exercise VO_2max scores and post-exercise VO_2max scores with Tai Chi in cancer patients after chemotherapy.

Alternative Hypothesis (H1): There is a significant difference between pre-exercise VO_2max scores and post-exercise VO_2max scores with Tai Chi in cancer patients after chemotherapy.

MATERIALS AND METHODS

This was a quasi-experimental study that commenced in March 2022 and was completed in September 2022 in Guwahati, Assam, India. Ethical approval for the study was obtained from the Institutional Ethics Committee (IEC) of the PEWS Group of Institutes (IEC number: CPMS/DV/SSUHS/1231/Jul/21). This study was affiliated with the College of Physiotherapy and Medical Sciences under Srimanta Sankaradeva University of Health Sciences, Guwahati, Assam. Written informed consent was obtained from all participants prior to their inclusion in the study.

Data were collected from cancer patients who had completed the course of chemotherapy at the North East Cancer Hospital and B. Boruah Cancer Institute in Guwahati.

Inclusion criteria:

- Patients diagnosed with breast cancer, stomach cancer, or colorectal cancer at stage II who have completed all doses of chemotherapy, verified by investigations.
- Willingness to engage in Tai Chi exercises.
- Both male and female individuals.
- Age range: 20-60 years.

Exclusion criteria:

- Patients who are unable to perform activities of daily living were not considered.
- Patients exhibiting extreme emotional instability or cognitive difficulties.
- Those with additional incapacitating diseases that could prevent participation in exercise (such as unstable angina, acute heart failure, severe chronic obstructive pulmonary disease, and neurological or orthopaedic conditions) were not included in the study.
- Lung cancer patients.

Sample size:

$$n=\frac{(Z_{\alpha/2}+Z_{\beta})^2\times 6^2}{\Delta^2}$$

$Z_{\alpha/2}$=1.96 (for 95% confidence level)

Z_{β}=0.84 (for 80% power)

6=5.36 (from previous study) [15]

Δ=2.98 (expected mean diff.)

Now, $n=\frac{(1.96+0.84)^2\times(5.36)^2}{(2.98)^2}$

$=\frac{7.84\times 28.73}{8.88}$

$=\frac{225.2432}{8.88}$

=25.37

≈26

Adjusted for 10% dropout

nadj=26/1-0.10=26/0.9=28.89

≈29

Total 30 considered

Study Procedure

A total of 30 subjects were assessed for eligibility. Seven did not meet the inclusion criteria, two declined to participate, and 21 subjects were enrolled, out of which there were seven dropouts. In total, 15 participants completed the entire intervention. The subjects were informed about the methods, and basic demographic data, which included gender, height, weight, type of cancer, chemotherapy doses, and vital signs, were recorded. Following this, the participants were taught the Tai Chi exercises through self-demonstration, video instructions, and an exercise booklet. They were instructed to perform Tai Chi exercises for 30 minutes per session, twice a week, for six weeks at home. After the six-week intervention, VO_2max was reassessed to evaluate any changes.

Instruments used:

- Paper and pencil
- Pulse oximeter
- Stethoscope
- Blood pressure apparatus

Intervention strategy: All patients received self-demonstration instruction in Tai Chi exercises, and each participant received an exercise booklet and video to follow at home for six weeks. The patients worked out under close supervision two days a week. During the six-week period, each patient engaged in a 30-minute Tai Chi exercise intervention at home. The patients were asked to provide verbal feedback at the conclusion of each week.

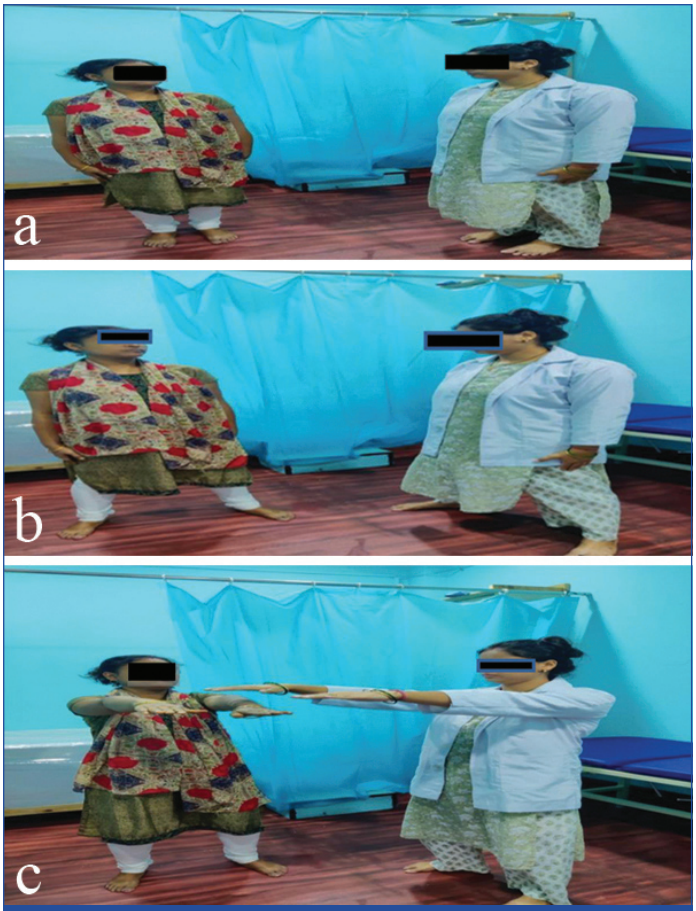
The following forms of the Yang style of Tai Chi were administered [Table/Fig-1-7]:

- Commencing form
- Parting the Wild Horse's Mane
- White Crane Flashing Wings
- Brush Knee
- Playing the Lute
- Cross Hands
- Closing form [10].

The flow and process of the study are explained in [Table/Fig-8].

STATISTICAL ANALYSIS

Statistical analysis was conducted using SPSS software version 25. The test of normality was performed using the Shapiro-Wilk test, and the parametric test applied was the paired t-test. Statistical significance was set at $p<0.05$, while $p<0.001$ was considered highly significant.



[Table/Fig-1]: Commencing form. a) Stand upright without tension; b) Gently lift left foot, setting it shoulder-width apart; c) With a slow breath in, lift hands to chest level, palms downward.

[Table/Fig-2]: Parting the wild horse's mane. a) Raise right hand above the left, shift weight to the right foot; b) Shift weight forward to form a bow stance, separating the hands.

[Table/Fig-3]: White Crane flashing wings. a) With weight on the left foot, step gently forward with the right, ending left hand over right; b) Shift weight back to the right foot, bringing hands together; c) Balance on the back foot right hand rises, palm in; left palm turns down.

[Table/Fig-4]: Brush knee; a) Right hand moves near the left elbow, weight on the right foot; b) Step towards the left with left foot lifting the right hand, lowering the left; c) Weight moves forward, left hand near hip, right hand extends.

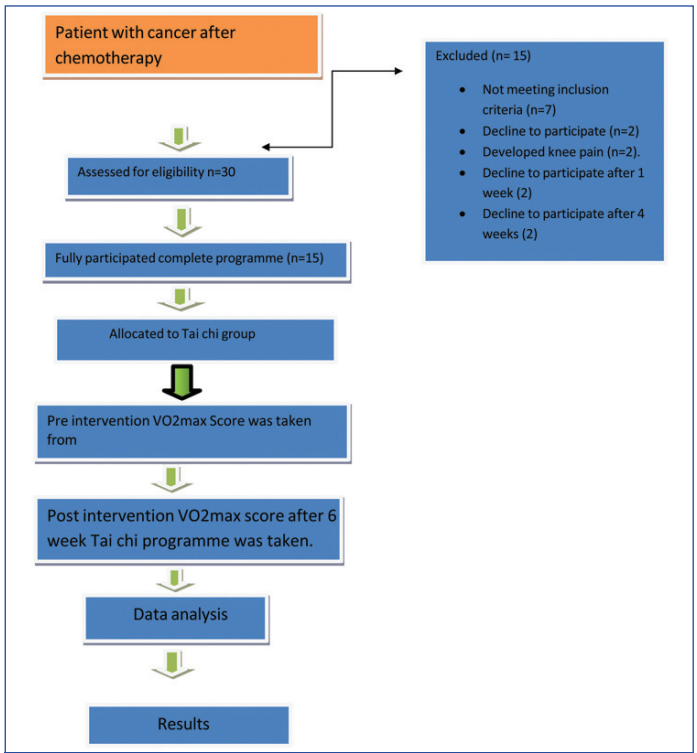
[Table/Fig-5]: Playing the lute.

[Table/Fig-6]: Cross hands.

RESULTS

In this study, 15 post-chemotherapy patients participated in a 6-week Tai Chi practice. Baseline VO_2max was measured prior to

[Table/Fig-7]: Closing form; a) Place feet shoulder-width apart, extend arms with palms down; b) Gently lift left foot, setting it shoulder-width apart; c) Bring feet back together.



[Table/Fig-8]: Flowchart for the participants.

exercise, and it was measured again after the 6-week programme had concluded. Descriptive statistical analysis of age and gender revealed that the gender distribution was 33% for men and 67% for women, with the mean and standard deviation of age being 42.80 and 8.411, respectively. We discovered that the mean VO_2max (initial value) was 32.9213, while the post value was 36.6353, indicating that the mean value increased following exercise. The Shapiro-Wilk Kolmogorov-Smirnov test was used to confirm the normal distribution, and the paired sample test was employed to assess the p-value, as the pre- and post-values of VO_2max adhered to the normality assumption [Table/Fig-9]. The pre- and post-

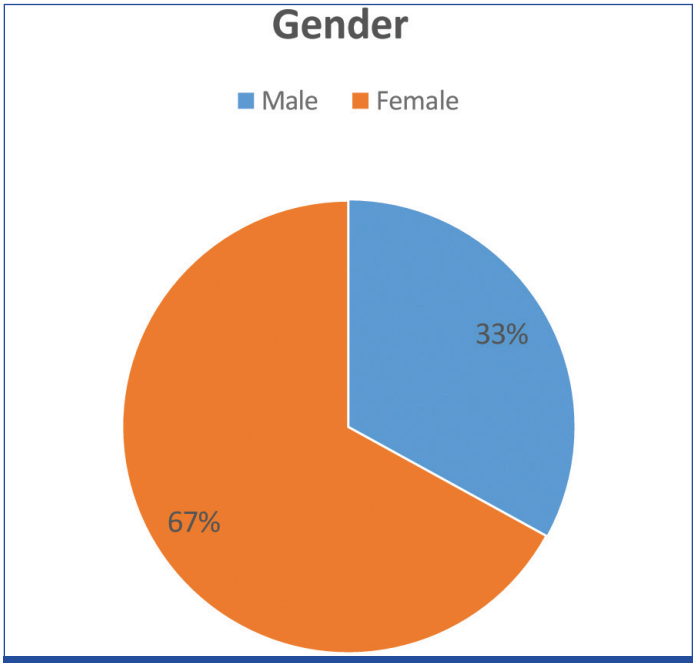
Tests of normality								
	Kolmogorov-Smirnov[a]				Shapiro-Wilk			
	Statistic	df	Sig.	Remark	Statistic	Df	Sig.	Remark
VO_2max Pre value	0.171	15	0.200*	NS	0.908	15	0.126	NS
VO_2max Post value	0.096	15	0.200*	NS	0.952	15	0.560	NS
Pre Ex RHR	0.243	15	0.180	NS	0.912	15	0.144	NS
Post Ex RHR	0.187	15	0.166	NS	0.915	15	0.164	NS

[Table/Fig-9]: Normality test.
NS: Not significant; Pre Ex RHR: Pre exercise resting heart rate; Post Ex RHR: Post exercise resting heart rate

VO_2max values were statistically significant at p<0.001 in the paired sample test for normally distributed data.

This means that both pre- and post-values of VO_2max follow the normality assumption, so we need to use a parametric test.

Pre- and post-values of Resting Heart Rate (RHR) also follow the normality assumption. Of the study population, 67% were males and 33% were females [Table/Fig-10]. The mean pre-VO_2max value was 32.92, and the mean post-VO_2max value was 36.63, as described in detail in [Table/Fig-11]. The mean difference between the pre-test and post-test of VO_2max showed a statistically significant difference (p<0.001) [Table/Fig-12]. There is a significant difference between the pre- and post-values of VO_2max [Table/Fig-13]. [Table/Fig-14, 15] show the pre- and post-mean values of VO_2max across different age groups and genders.



[Table/Fig-10]: Pie distribution of gender characteristics.

Descriptive statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	15	30	59	42.80	8.411
VO_2max pre value	15	27.00	36.30	32.9213	3.00219
VO_2max post value	15	29.64	40.71	36.6353	3.00237

[Table/Fig-11]: Descriptive summary of VO_2max.

VO_2max	Pre-test	Post-test	Difference	t-value
Mean±SD	32.9213±3.00219	36.6353±3.00237	3.7140±0.0002	-11.091
p-value	<0.001			

[Table/Fig-12]: Mean difference between pre-test and post-test of VO_2max. Significant at p<0.001

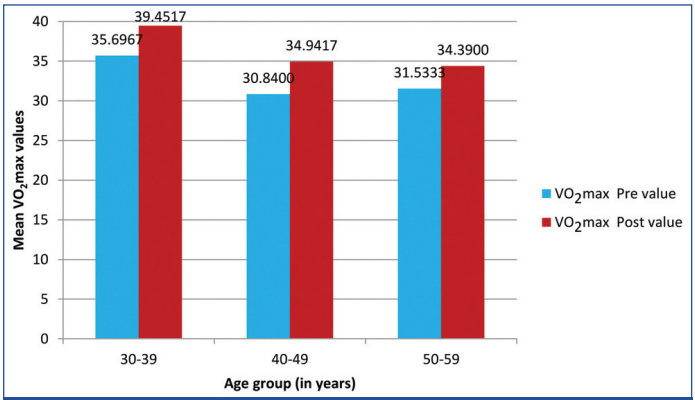
The mean pre-exercise RHR is 81.27, and the mean post-exercise RHR is 72.93. Details are described in [Table/Fig-16]. Therefore, there is a significant difference between the pre- and post-values of RHR [Table/Fig-17]. The mean RHR by age group-wise distribution is given in [Table/Fig-18].

DISCUSSION

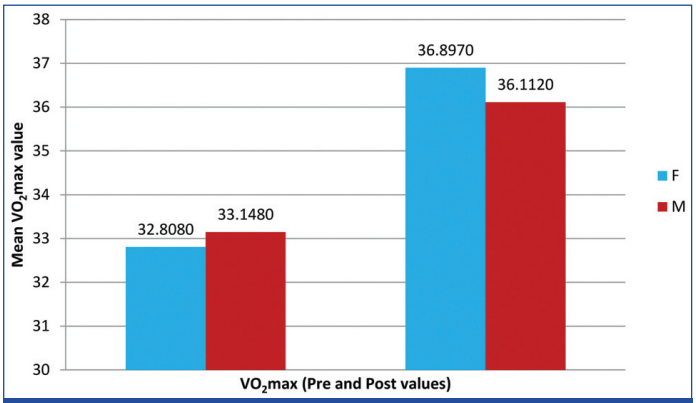
The objective of the study was to determine how effective Tai Chi exercises are in improving VO_2max among cancer patients after chemotherapy. In this study, 15 post-chemotherapy patients participated in a 6-week Tai Chi programme, and a significant difference in VO_2max was observed, with the mean value rising from 32.9213 to 36.64, and a p-value of <0.001 within a 95% confidence interval. These findings suggest that Tai Chi could be an effective intervention for improving VO_2max.

Paired sample test								
	Paired differences							
				95% Confidence interval of the difference				
VO_2max	Mean	Std. Deviation	Std. Error mean	Lower	Upper	T	Df	S (Two-tailed)
Pre-value - Post-value	-3.714	1.29689	0.33486	-4.43219	-2.99581	-11.091	14	0.000

[Table/Fig-13]: Paired t-test for related pre post-test of VO_2max.
***Significant at p<0.001



[Table/Fig-14]: Graph of mean value VO_2max age groupwise.



[Table/Fig-15]: Graph for mean value of VO_2max genderwise.

Descriptive statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Pre Ex RHR	15	72	95	81.27	6.595
Post Ex RHR	15	66	85	72.93	5.021

[Table/Fig-16]: Descriptive summary of RHR.
Pre Ex RHR: Pre exercise resting heart rate; Post Ex RHR: Post exercise resting heart rate

Current guidelines suggest moderate to vigorous aerobic and resistance exercise to manage acute, long-term, and late effects of cancer. However, many cancer survivors may not be able or willing to engage in high-intensity exercise during or after challenging treatment [16]. Chemotherapy-related fatigue is experienced by 80-90% of patients undergoing cancer treatment and is a significant, independent factor that lowers health-related quality of life. Additionally, cancer treatment triggers the release of neuroactive agents in the periphery, which activate vagal afferent nerves and lead to reduced somatic muscle activity [6]. For these reasons, cancer patients are often reluctant to engage in vigorous exercise.

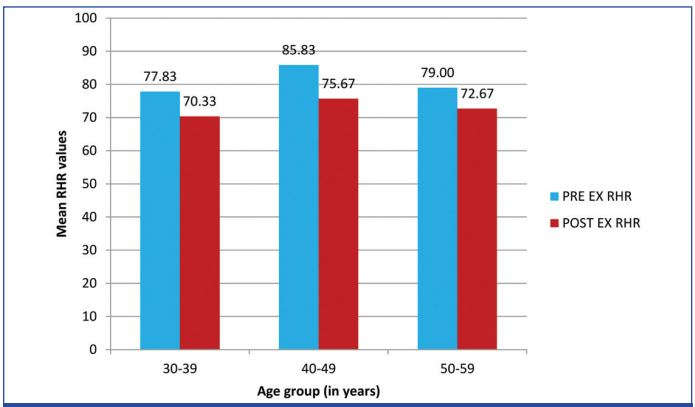
However, Tai Chi offers a gentle, equipment-free, mind-body exercise that combines static and dynamic postures with controlled breathing techniques. Recently, research into Tai Chi's effects on health and well-being has grown significantly. Numerous studies have shown that Tai Chi can provide various physical and psychological benefits, such as reducing psychological stress, anxiety, and depression, while enhancing quality of life and cardiovascular health [17]. Lu WA et al., found that, in the short term, Tai Chi improved vagal modulation and shifted sympathovagal balance towards reduced sympathetic activity [18].

Tai Chi, a traditional Chinese martial art, is recognised as low to moderate intensity aerobic exercise (Smith LL et al., 2015; Hu YN et al., 2016) that may also offer potential benefits for cardiac rehabilitation [19,20]. The possible mechanism behind this effect is that upper body movements in Tai Chi often involve thoracic expansion and stretching, which may strengthen the respiratory muscles. Additionally, Tai Chi's diaphragmatic breathing techniques may help to reshape breathing patterns by reducing breath frequency, keeping the airways open longer, and engaging the respiratory muscles more effectively [16,17].

Based on this research, it is assumed that Tai Chi helps maintain sympathovagal balance, which may reduce heart rate in cancer patients and increase the diastolic filling phase. This improvement allows the heart to efficiently sustain cardiac output, thereby enhancing maximal oxygen consumption (VO_2max).

Paired differences									
				95% Confidence interval of the difference					
	Mean	Std. Deviation	Std. Error mean	Lower	Upper	t	Df	Sig. (Two-tailed)	Remark
Pre Ex RHR - Post Ex RHR	8.333	3.677	0.950	6.297	10.370	8.776	14	0.000	***

[Table/Fig-17]: Paired t-test for related pre post-test of RHR.
***Significant at p<0.001



[Table/Fig-18]: Graph of mean value RHR age groupwise.

The increase in post-intervention VO_2max was most pronounced in participants aged 30-39 years, likely due to the general trend of VO_2max gradually decreasing with age at a rate of about 10% per decade after the age of 25 years, and more specifically, it was suggested to be 15% between the ages of 50 and 75 years [21-23]. This age-related decline in VO_2max stems from several factors: a decrease in maximum heart rate and stroke volume, reduced blood volume due to pooling from a less efficient muscle pump action in the extremity valves, stiffening of heart muscle fibres, thickening and stiffening of arterial walls, decreased peripheral oxygen extraction, and a reduced maximal arteriovenous oxygen difference (A-VO2) [24].

Limitation(s)

A few patients experienced knee pain during the process; thus, screening of BMI could have been taken into account. Daily supervision of Tai Chi exercises could not be conducted.

CONCLUSION(S)

Tai Chi is an effective intervention for improving maximal oxygen consumption and, thereby, enhancing aerobic capacity. Therefore, Tai Chi can be used as an intervention protocol for increasing cardiorespiratory endurance in cancer patients post-chemotherapy.

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PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Physiotherapy, Assam Down Town University, Guwahati, Assam, India.
2. Associate Professor, Department of Physiotherapy, The Assam Royal Global University, Guwahati, Assam, India.
3. Assistant Professor, Department of Physiotherapy, Girijananda Chowdhury University, Guwahati, Assam, India.
4. Assistant Professor, Department of Physiotherapy, The Assam Royal Global University, Guwahati, Assam, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Seema Das,
Assam Down Town University, Chandrapur Subdistrict, Sankar Madhab Path, Gandhi Nagar, Panikhaiti, Guwahati-781026, Assam, India.
E-mail: drseema575@gmail.com

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