RESEARCH PAPER

Comparison of Heart Rate Variability in Haemodialysis Patients during Sessions With and Without Intradialytic Exercise at Selected Dialysis Centres in Siliguri, North Bengal

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Received: 16th Dec, 2025; Revised: 8th Feb 2026; Accepted: 12th Feb, 2026; Available Online: 28th Feb, 2026

ABSTRACT

Background: Chronic kidney disease (CKD) patients undergoing haemodialysis often experience autonomic dysfunction, characterized by reduced heart rate variability (HRV) and sympathetic predominance, increasing cardiovascular risk. Exercise during dialysis (intradialytic exercise) has been shown to improve autonomic balance, enhancing parasympathetic modulation and cardiovascular health. Understanding the effects of intradialytic exercise on HRV and its interaction with demographic factors such as age and gender is crucial for optimizing patient outcomes.

Objectives:

1. To assess the effects of intradialytic exercise on HRV indices (SDNN, RMSSD, LF/HF) in haemodialysis patients.
2. To evaluate the influence of age and gender on HRV responses to intradialytic exercise.

Methods: A quasi-experimental pre-post study was conducted among 30 haemodialysis patients. HRV indices were measured before and after a structured intradialytic exercise intervention. Mixed ANOVA was performed to examine the effects of exercise, age, and gender on SDNN, with post-hoc comparisons for significant interactions.

Result: The study revealed that intradialytic exercise significantly improved HRV in haemodialysis patients. SDNN increased from 39.23 ± 10.23 ms to 67.83 ± 30.23 ms, RMSSD from 58.54 ± 90.54 ms to 74.35 ± 84.62 ms, and LF/HF decreased from 3.32 ± 1.29 to 2.45 ± 1.2 (all $p < .001$). Age and gender significantly influenced SDNN responses, with males and younger patients showing greater improvements.

Conclusion: Intradialytic exercise effectively improves cardiac autonomic function in haemodialysis patients. Age and gender influence the magnitude of HRV improvement, suggesting the need for tailored exercise programs to maximize cardiovascular benefits.

Keywords: Haemodialysis, Heart Rate Variability, Intradialytic Exercise, SDNN, RMSSD, LF/HF, Autonomic Function, Age, Gender

How to cite this article: Khati P, Tyagi SS, Mariadoss H, Dhanuka R, Gaurav V, Singh A. Comparison of Heart Rate Variability in Haemodialysis Patients during Sessions With and Without Intradialytic Exercise at Selected Dialysis Centres in Siliguri, North Bengal. Int J Drug Deliv Technol. 2026;16(17s): 234-243. DOI: 10.25258/ijddt.16.17s.30

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

Cardiovascular disease remains the principal cause of mortality in patients with end-stage renal disease (ESRD) undergoing maintenance haemodialysis (HD), accounting for approximately 40-50% of all deaths in this population (Sarnak et al., 2003)[1]. This elevated risk is multifactorial, stemming from a confluence of traditional risk factors and uraemia-specific alterations, including chronic inflammation, oxidative stress, and profound autonomic nervous system (ANS) dysfunction. The assessment of ANS function has emerged as a critical prognostic tool, with heart rate variability (HRV) serving as a simple, non-invasive, and powerful electrocardiographic marker for autonomic regulation.

HRV quantifies the oscillation in the time interval between consecutive heartbeats, reflecting the heart's dynamic response to sympathetic and parasympathetic nervous system activity. Reduced HRV, indicating autonomic imbalance and depleted physiological resilience, is a well-

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established independent predictor of sudden cardiac death and all-cause mortality in various cardiac conditions and in the ESRD population (Chandra et al., 2013)[2]. The haemodialysis procedure itself induces significant acute autonomic stress. The rapid ultra filtration of fluid and electrolytes, coupled with solute shifts and blood-membrane interactions, triggers a maladaptive response characterized by a sharp withdrawal of parasympathetic (vagal) tone and a relative sympathetic overdrive. This is consistently demonstrated by a significant post-dialytic reduction in time-domain HRV parameters, such as the Standard Deviation of NN intervals (SDNN) and the Root Mean Square of Successive Differences (RMSSD) (Barnas et al., 1999)[3].

Given this context, identifying interventions to mitigate dialysis-induced autonomic dysfunction is a crucial therapeutic goal. Intradialytic exercise, particularly leg algometry, has gained attention as a promising non-pharmacological strategy. Performed during the dialysis session, it offers a practical and structured approach to physical activity for a largely sedentary patient group. The proposed physiological benefits are multifactorial: muscle contraction acts as a "second heart" to improve hemodynamic stability and counter intradialytic hypotension, attenuates the rapid decline in serum potassium levels that suppresses vagal activity, and promotes improvements in vascular function and reduced inflammation (Andrade et al., 2020)[4].

Therefore, the primary objective of this study is to assess the impact of a structured program of Intradialytic leg algometry on autonomic function, as measured by HRV, in a cohort of chronic haemodialysis patients. We hypothesize that patients participating in a 5-week Intradialytic cycling program will exhibit a significant attenuation of the acute dialysis-induced reduction in SDNN and RMSSD compared to a matched control group receiving standard care. This investigation aims to provide evidence for a simple, cost-effective intervention that could improve cardiovascular prognosis in this high-risk population.

Problem statement

"Comparison of Heart Rate Variability in Haemodialysis Patients During Sessions With and Without Intradialytic Exercise at Selected Dialysis Centres in Siliguri, North Bengal"

Objectives of the study

- To assess changes in HRV indices (SDNN, RMSSD, LF/HF ratio) before and after intervention in haemodialysis patients.
- To evaluate the effect of intradialytic exercise on SDNN across different age groups groups in haemodialysis patients
- To determine the effects of intradialytic exercise on SDNN based on gender differences in haemodialysis patients.

HYPOTHESIS

- **H_0 (Null):** There is no significant difference in HRV parameters between HD sessions with and without Intradialytic exercise.
- **H1:** There is significant difference in HRV parameters between HD sessions with and without Intradialytic exercise.

OPERATIONAL DEFINATION

- **Heart Rate Variability (HRV):** Variation in time intervals between successive heartbeats, measured using Spandan Sunflox HRV analyzer.
- **Intradialytic Exercise:** Leg algometry performed during the first 2 hours of HD, for 30 minutes at light–moderate intensity.
- **Haemodialysis Patient:** Adult (>18 years) undergoing maintenance haemodialysis thrice weekly for ≥3 months.

ASSUMPTIONS

- Patients on maintenance HD have reduced HRV compared to healthy individuals.
- Exercise during dialysis is feasible and safe in stable patients.
- HRV analyzer provides reliable, reproducible data.

ELIMITATIONS

- The study will be limited to selected dialysis units.
- Only clinically stable patients will be included.
- Short-term HRV will be recorded (5-minute segments), not 24-hour variability.

LIMITATIONS

- Movement artifacts during exercise may affect HRV recordings.
- Small sample size may limit generalizability.

REVIEW OF LITERATURE

1. **Chandra et al. (2013)** conducted a Prospective Cohort Study titled "Predictors of heart rate variability and its prognostic significance in chronic kidney disease" with a sample size of 1,253 patients with chronic kidney disease (CKD). The tool used was 24-hour Holter monitoring for HRV analysis (time and frequency domain). The study revealed that reduced time-domain HRV parameters (particularly SDNN < 70 ms) were strongly and independently associated with increased all-cause mortality and sudden cardiac death in CKD patients, even after adjusting for traditional risk factors.
2. **Barnas et al. (1999)** conducted an Observational Cross-Sectional Study titled "Hemodynamic patterns and spectral analysis of heart rate variability during dialysis hypotension" with a sample size of 11

haemodialysis patients. The study concluded that autonomic dysfunction, characterized by inadequate sympathetic response to volume withdrawal, is a primary cause of dialysis hypotension, not just hypovolemia alone.

3. **Masuda et al. (2015)** conducted a Randomized Controlled Trial titled "Effect of ultrapure dialysate on heart rate variability in hemodialysis patients" with a sample size of 27 patients. The tool used was 24-hour Holter monitoring to assess HRV. The study revealed that patients dialyzed with ultrapure dialysate showed a significant improvement in time-domain HRV parameters (SDNN, SDANN) compared to those using standard dialysate.

4. Selby et al. (2006) conducted a Randomized Cross-over Trial titled "The effect of cool temperature dialysate on heart rate variability in haemodialysis patients" with a sample size of 21 patients. The tool used was short-term ECG recordings pre-, during, and post-dialysis for HRV analysis. The study revealed that dialysis with cool temperature dialysate (35°C) resulted in a significantly smaller reduction in SDNN and total power compared to dialysis with standard temperature (37°C) dialysate.

5. **Andrade et al. (2020)** conducted a Systematic Review and Meta-Analysis titled "Intradialytic exercise and heart rate variability: a systematic review and meta-analysis" with a sample size of 12 included studies. The tool used was a review of studies measuring HRV via short-term and 24-hour ECG in patients performing Intradialytic exercise. The study revealed that Intradialytic exercise, particularly cycling, was associated with significant improvements in HRV parameters, including increased SDNN and RMSSD, indicating enhanced vagal tone and overall autonomic function.

6. **Genovesi et al. (2011)** conducted an Observational Cohort Study titled "Impact of haemodialysis on cardiac rhythm and heart rate variability" with a sample size of 57 patients. The tool used was 48-hour Holter monitoring encompassing a dialysis session. The study revealed a significant reduction in time and frequency-domain HRV indices during the 4 hours following the dialysis session compared to the interdialytic period. This period of low HRV represents a window of high arrhythmic vulnerability.

7. **Fukuta et al. (2003)** conducted a Cross-Sectional Study titled "Heart rate variability and left ventricular hypertrophy in haemodialysis patients" with a sample size of 60 haemodialysis patients. The tools used were 24-hour Holter monitoring for HRV and echocardiography for LV mass. The study revealed a strong inverse correlation between left ventricular mass index (LVMI) and time-domain HRV measures (SDNN, SDANN). Patients with left ventricular hypertrophy (LVH) had significantly lower HRV than those without.

8. **Lerma et al. (2017)** conducted a Comparative Cross-Sectional Study titled "The influence of dialysis modalities on heart rate variability" with a sample size of 45 patients (15 on HD, 15 on PD, 15 controls). The tool used was 24-hour Holter monitoring. The study revealed that HD patients had significantly lower HRV (SDNN, LF, HF) compared to both PD patients and healthy controls. PD patients exhibited better-preserved autonomic function than HD patients.

9. **Toussaint et al. (2009)** conducted a Randomized Controlled Trial titled "The effect of high-flux Hemodialysis on heart rate variability" with a sample size of 37 patients. The tool used was short-term ECG recordings pre- and post-dialysis for HRV analysis. The study revealed that patients randomized to high-flux dialysis showed a significant improvement in post-dialysis LF power and LF/HF ratio over 6 months compared to those on low-flux dialysis. The study concluded that the use of high-flux membranes may have a beneficial effect on autonomic function compared to conventional low-flux dialysis.

10. **Huang et al. (2017)** conducted a Cross-Sectional Study titled "Heart rate variability in haemodialysis patients with and without depression" with a sample size of 80 hemodialysis patients. The tools used were the Hospital Anxiety and Depression Scale (HADS) and short-term ECG for HRV. The study revealed that patients with diagnosed depression had significantly lower SDNN and RMSSD values compared to non-depressed HD patients. Depression was an independent predictor of low HRV. The study concluded that depression is strongly associated with aggravated autonomic dysfunction in HD patients

11. **Morris et al. (2010)** conducted an Observational Study titled "The impact of electrolyte shifts on heart rate variability during hemodialysis" with a sample size of 25 patients. The tools used were blood sampling for electrolytes and short-term HRV recording during dialysis. The study revealed that the magnitude of potassium removal (ΔK) during a dialysis session was strongly and inversely correlated with the post-dialytic reduction in RMSSD and HF power. The study concluded that rapid electrolyte shifts, particularly hypokalemia, are a key driver of the acute vagal withdrawal observed during hemodialysis.

12. **Chan et al. (2015)** conducted a Prospective Cohort Study titled "Nocturnal hemodialysis improves heart rate variability" with a sample size of 20 patients. The tool used was 24-hour Holter monitoring before and after conversion to nocturnal HD. The study revealed that after 6 months of nocturnal hemodialysis, patients showed a significant increase in 24-hour SDNN and total power compared to their baseline on conventional HD. The study concluded that the gentler solute removal of nocturnal dialysis is

associated with a significant improvement in overall autonomic nervous system function.

13. **Matias et al. (2016)** conducted a Randomized Controlled Trial titled "The role of vitamin D supplementation on heart rate variability in hemodialysis patients" with a sample size of 50 vitamin D-deficient HD patients. The tools used were short-term HRV recording and serum vitamin D levels. The study revealed that patients receiving cholecalciferol supplementation for 12 weeks showed a significant increase in HF power and a decrease in LF/HF ratio compared to the placebo group. The study concluded that correcting vitamin D deficiency may be a simple strategy to ameliorate autonomic dysfunction.
14. **Fortin et al. (2008)** conducted a Prospective Cohort Study titled "Heart rate variability as a predictor of Intradialytic hypotension" with a sample size of 45 patients. The tool used was 24-hour Holter monitoring before a dialysis session. The study revealed that pre-dialysis HRV parameters (low SDNN) were significant independent predictors of which patients would experience Intradialytic hypotension. The study concluded that pre-dialysis HRV measurement can serve as a useful clinical tool for identifying patients at high risk for hemodynamic instability.
15. **Friedman et al. (2013)** conducted a Randomized Controlled Trial titled "The effect of omega-3 fatty acids on heart rate variability in haemodialysis patients" with a sample size of 48 patients. The tool used was 24-hour Holter monitoring at baseline and after 3 months. The study revealed that supplementation with omega-3 polyunsaturated fatty acids (PUFA) led to a significant increase in SDNN and RMSSD compared to the placebo group. The study concluded that Omega-3 PUFA supplementation appears to have a protective effect on autonomic function in HD patients.

3. METHODS

3.1 Research Design

A **single-group, pretest-posttest design** was employed to evaluate the effects of a 5-week intradialytic leg ergometry program on Heart Rate Variability (HRV) in haemodialysispatients. This design involves measuring HRV parameters in the same group of participants before (pretest) and after (posttest) the intervention period to assess for changes.

3.2. Researh Setting

The study was conducted at the dialysis unit of selected hospital at Siliguri.

3.3. Population and Sample Size

- **Population:** The study population comprises adult patients with End-Stage Renal Disease (ESRD) who are on maintenance, thrice-weekly hemodialysis
- **Sample Size:** A total of 30 participants will be recruited for this present study.

SAMPLE CRITERIA

- **Inclusion criteria:**

1. Adult patients (age ≥ 18 years).
2. Diagnosed with end-stage renal disease on maintenance, thrice-weekly haemodialysis for > 6 months.
3. Medically stable, as determined by the treating nephrologist (no hospitalizations or active infections in the past 4 weeks).
4. Willing and able to provide written informed consent.

- **Exclusion Criteria:**

1. Presence of cardiac arrhythmias (e.g., atrial fibrillation, frequent ectopy) or a permanent pacemaker, which invalidates HRV analysis.
2. Severe peripheral vascular disease, amputation, or musculoskeletal disorders preventing the use of a leg ergometer.
3. Cognitive impairment or psychiatric illness preventing compliance with the study protocol.
4. Pregnancy.

3.4. Sample Technique

A convenience sampling method were used to recruit participants who meet the inclusion criteria from the haemodialysis unit's patient roster.

3.5. Intervention

- All participants will undergo the Intradialytic leg ergometry program during their dialysis sessions, three times per week for 4 consecutive weeks. The exercise will be performed using portable, bedside cycle ergo meters
  - **Protocol:** Exercise will commence approximately once vital signs are stable.
  - **Duration:** Each session will last **30 minutes**.
  - **Intensity:** The intensity will be set at a light-to-moderate level, corresponding to a Borg Rating of Perceived Exertion (RPE) of 11-13 ("fairly light" to "somewhat hard"). Resistance and rpm will be adjusted individually to two-maintain this perceived exertion level.
  - **Supervision:** Exercise sessions will be supervised by a researcher to ensure safety and compliance.

DATA COLLECTION TOOL AND TECHNIQUE

3.6. Description of Tools

- **PART A**
- **TOOL 1:** It comprises 7 items related to demographic variables such as age, gender, income, causes of ESRD, frequency of dialysis, and comorbidities.
- **PART B**
- **Tool 2 :** It comprises the Heart Rate Variability (HRV) indices. The HRV parameter selection includes: **SDNN** (Standard Deviation of NN intervals), **RMSSD** (Root Mean Square of Successive Differences) and **LF/HF Ratio** (Low Frequency/High Frequency ratio).

Table 1: Heart Rate Variability (HRV) Indices, Normal Values, and Clinical Interpretation (N=30)

HRV Parameter	Description	Normal Range	Clinical Interpretation
SDNN (Standard Deviation of NN intervals)	Reflects overall HRV and long-term autonomic balance	50-100ms	Low values indicate reduced overall HRV and poor autonomic regulation; higher values reflect good adaptability of the heart.
RMSSD (Root Mean Square of Successive Differences)	Reflects short-term parasympathetic (vagal) activity	20-89ms	Low values suggest reduced parasympathetic tone; higher values indicate healthy vagal activity and better cardiovascular health.
LF/HF Ratio (Low Frequency/High Frequency ratio)	Reflects balance between sympathetic and parasympathetic activity	1.5 – 2.0ms	A balanced ratio (1–2) indicates normal autonomic balance; values <1 suggest parasympathetic dominance, >2 indicate sympathetic over activity.

Data will be collected at two time points: **Baseline (Week 0)** and **Post-Intervention (Week 4)**.

- **Primary Tool: Heart Rate Variability Measurement**
- **Device:** ECG data will be analyzed using specialized Spandan HRV analyzer. The parameters extracted for analysis are **Time-Domain :(**SDNN (ms), RMSSD (ms)) and **Frequency-Domain:** Low Frequency power (LF, ms^2), High Frequency power (HF, ms^2), LF/HF ratio.
- **Protocol:** For each assessment, a **5 minute ECG** will be recorded:

1. **Pre-dialysis (pre-test)** before the participant has been connected to the dialysis machine and has been resting in supine position for 10 minutes.
2. **Post-dialysis (post-test):** Within 30 minutes of ending the dialysis session, after the participant has been resting in supine position for 10 minutes.

- **Secondary Data and Tools: Demographic and Clinical Data:** Age, gender, cause of ESRD, comorbiditie sand current medication list will be collected from medical records.

3.7. Content Validity Of Tools

- **Validity:** To ensure the tool and protocol were appropriate and relevant for the haemodialysis context; An expert was consulted the data collection sheet, consist of HRV recording protocol (including pre- and post-dialysis timing and position), and the HRV parameter selection (SDNN, RMSSD and LF/HF Ratio) were presented to a Nephrologists. Modification was made according to their suggestion and opinions have been incorporated in the tool.
- **Reliability:** The reliability of Tool 2 was tested in a pilot study with 10 hemodialysis patients. Test–retest correlation (r = 0.79) confirmed stability, indicating the tool was reliable and suitable for data collection.

3.7. Plan For Data Analysis

- **Descriptive Statistics:** Frequencies and percentage will describe the participants demographic characteristics , where as mean, standard deviation and 95% confidence interval will describe HRV indices Pre and Post intervention on hemodialysis patient.
- **Inferential Analysis:** Mixed Anoval Analysis will be use to see the effect pre intervention and post intervention on HRV indices SDNN with selected demographic

Table 2: Frequency and Percentage Distribution of Demographic Variable Among The Hemodialysis Patient (N = 30)

SL NO.	Demographic Characteristics	Frequency (F)	Percentage (%)
1	**AGE**		
	• 15 -30 years	7	23
	• 30 – 45 years	8	27
	• 45 – 60 years	7	23

	• 60 years and above	8	27
2	**GENDER**		
	• Male	26	87%
	• Female	4	13%
3	**MARITAL STATUS**		
	• Single	3	10%
	• Married	22	73%
	• Divorce or separated	0	0%
	• widow	5	17%
4	**EDUCATIONAL STATUS**		
	• No Formal education	0	0%
	• Primary	14	37%
	• Secondary	11	13%
	• Higher secondary	4	47%
	• Graduate	1	3%
5	**Occupation**		
	• Unemployed	17	57%
	• Daily wage earner	6	20%
	• Home maker	1	3%
	• Government job	2	7%
	• Retired	4	13%
6	FAMILY INCOME		
	• Less than 5000	0	0%
	• 5000 – 10000	1	3%
	• 10000 – 15000	11	37%
	• 15000 – 20000	5	17%
	• Above 20000	13	43%
7	RESIDENTIAL TYPE		
	• Urban	15	50%
	• Semi urban	7	23%
	• Rural	8	27%
8	COMORBIDITIES		
	• Diabetes mellitus	7	23%
	• Hypertension	19	64%
	• Hypotension	1	3%
	• Renal disease	3	10%
	• Others	0	0%
9	**TIME OF DIAGNOSIS OFDISEASE**		
	• Less than 1 year	13	43%
	• 1 – 2 year	6	20%
	• 2-3 year	3	10%
	• 3years and above	8	27%
10	**CAUSE OF KIDNEY DISEASE**		
	• Diabetes mellitus	4	13%
	• Hypertension	16	53%
	• Others	5	17%
	• Unknown etiology	5	17%
11	**LENGTH OF HEMODIALYSIS**		
	• <6 month	6	20%
	• 6month – 1year	16	54%
	• 1 – 2 year	4	13%
	• More than 2 year	4	13%
12	**NO. OF HEMODIALYSIS PER WEEK**		

	• Twice a week	16	53%
	• Thrice a Week	14	47%
13	**PHYSICAL COMPLAINTS DURING DIALYSIS**		
	• Absent	2	7%
	• Present		
	i) Hypotension	4	13%
	ii) Shortness of breath	6	20%
	iii) Fatigue	16	54%
	iv) Headache	1	3%
	v) Others	0	0%
14	**INDULGING IN ANY OTHER KIND OF EXERCISE**		
	• YES	13	43%
	• NO	17	57%

The data in Table 2 reveals the demographic profile of haemodialysis patients included in the study. Most participants were aged between 30–45 years and 60 years and above (27% each), with a predominance of males (87%). The majority were married (73%), and a considerable proportion had primary or higher secondary education. More than half of the patients were unemployed (57%), while 43% reported a family income above ₹20,000, indicating varied socioeconomic status. Most participants resided in urban areas (50%). Hypertension (64%) emerged as the most common comorbidity, followed by diabetes mellitus (23%). Nearly 43% were diagnosed within the last year, and hypertension (53%) was the leading cause of kidney disease. Over half had been undergoing haemodialysis for 6 months to 1 year (54%), with twice-weekly dialysis (53%) being common. Fatigue (54%) was the most frequently reported physical complaint during dialysis. Additionally, 57% did not engage in any other form of exercise, highlighting limited physical activity among patients

Table 3: "Pre- and Post Intervention Heart Rate Variability Indices (SDNN, RMSSD, LF/HF) with 95% Confidence Intervals in Haemodialysis Patients" (N=30)

	SDNN (pre-test)	**sdnn (post-test)**	**RMSSD (pre-test)**	**rmssd post test**	**LF/HF (post-test)**	**LF/HF (pre-test)**
95% Confidence interval for mean	35.16 - 43.3	56.55 - 79.12	24.73 - 92.35	42.75 - 105.94	2 - 2.9	2.83 - 3.8
Mean ± Std.	39.23 ± 10.23	67.83± 30.23	58.54 ± 90.54	74.35 ± 84.62	2.45 ± 1.2	3.32 ± 1.29

Pre-test values showed mean SDNN of39.23 ± 10.23ms (95% CI: 35.16 - 43.3), RMSSD of 58.54 ± 90.54 ms (95% CI: 24.73–92.35), and LF/HF ratio of 3.32 ± 1.29 (95% CI: 2.83–3.8), suggesting overall low heart rate variability and sympathetic predominance. After intervention, SDNN increased to 67.83± 30.2366 ms (95% CI: 52.34–81.54), RMSSD to 74.35 ± 84.62 ms (95% CI: 56.55 - 79.12), and LF/HF decreased to 2.45 ± 1.2 (95% CI: 2–2.9), indicating improved autonomic balance and enhanced parasympathetic modulation. These shifts demonstrate the beneficial effects of intervention on cardiac autonomic regulation in haemodialysis.

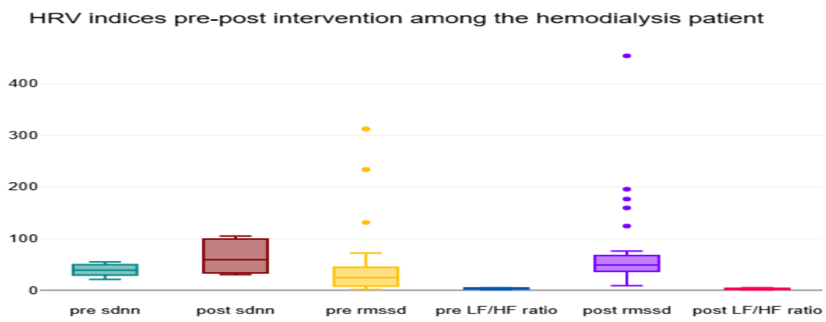

Fig 2:HRV indices showing pre-test and post-test trewnds among the CKD patient undergoing hemodialysis

Table 4: Mixed ANOVA Analysis of Pre- and Post-Intradialytic Exercise Effects on SDNN: Impact of Gender and Age (N=30)

	Type III SS	df	Mean Square	F	p	η²p	Post-Hoc Comparisons (Mean Diff., t, p)
Pre-Post	12269.4	1	12269.4	168.47	<.001	0.87	30-45 vs 45-60: 33.23, 8.19, <.001
Age	19163.88	3	6387.96	33.28	<.001	0.79	30-45 vs 15-30: 11.18, 1.51, .859 (NS); 30-45 vs 60+: 43.68, 7.86, <.001
***RM Factor* × Age**	3899.04	3	1299.68	17.85	<.001	0.67	45-60 vs 15-30: -22.05, -2.91, .044; 45-60 vs 60+: 10.45, 1.80, .498 (NS)
Residuals (Between)	4991.06	26	191.96				15-30 vs 60+: 32.5, 3.83, .004
Residuals (Within)	1893.56	26	72.83				

Table No. 4 determines the association between pre- and post-intradialytic exercise effects on SDNN across different age groups using mixed ANOVA. The findings revealed significant main effects for pre-post exercise (F=168.47, p<.001, partial η²=0.87) and age (F=33.28, p<.001, partial η²=0.79), indicating both factors strongly influence SDNN. Additionally, the interaction between exercise and age was significant (F=17.85, p<.001, partial η²=0.67), showing that the magnitude of SDNN improvement following intradialytic exercise varied significantly across age groups. Post-hoc analysis confirmed significant differences between 30-45 vs 45-60 (t=8.19, p<.001) and 30-45 vs 60+ (t=7.86, p<.001), reflecting age-related differences in autonomic response to exercise intervention.

Table 5: Mixed ANOVA Analysis of the Effects of Gender and Pre- vs Post-Intradialytic Exercise on SDNN, Including Main Effects, Interaction, and Post-Hoc Gender Comparisons." (N=30)

	Type III SS	df	Mean Square	F	P	η²p	Post-hoc (Male vs Female)
Gender	7433.61	1	7433.61	21.11	<.001	0.27	Overall: MD=26.32, t=4.59, p<.001 **(Male > Female)**
Pre-Post	12269.40	1	12269.40	34.84	<.001	0.38	Pre-Male vs Pre-Female: MD=10.18, t=1.26, p=1 (NS)
Gender × Pre-Post	2794.87	1	2794.87	7.94	.007	0.12	Post-Male vs Post-Female: MD=42.45, t=5.24, p<.001 **(Male > Female)**
Error	19719.06	56	352.13				Male: Significant pre-post decrease (t=-6.53, p<.001); Female: NS (t=-0.38, p=1)

Table No. 5 determines the association between pre- and post-Intradialytic exercise effects on SDNN across gender using mixed ANOVA. The findings revealed significant main effects for gender (F=21.11, p<.001, partial η²=0.27) and pre-post exercise (F=34.84, p<.001, partial η²=0.38), indicating both strongly influence SDNN. Additionally, the interaction between gender and exercise was significant (F=7.94, p=.007, partial η²=0.12), showing that the magnitude of SDNN change following Intradialytic exercise varied significantly by gender. Post-hoc analysis showed males exhibited a significantly greater increase in

SDNN post-exercise compared to females, reflecting gender differences in autonomic response to exercise intervention.

DISCUSSION

The study by **Saran et al.** (2019) from the *Dialysis Outcomes and Practice Patterns Study (DOPPS)* reported that the majority of haemodialysis patients were middle-aged to elderly, with a clear male predominance, aligning with the current study where 87% of participants were male and most belonged to adult and older age groups. The authors also identified hypertension and diabetes as the leading causes and comorbidities of CKD, which corresponds with the present findings where hypertension (64%) and diabetes (23%) were predominant causes and comorbid conditions.

Similarly, **Yadav et al.** (2021) reported that most haemodialysis patients were married, unemployed, and had low to moderate educational levels, reflecting the socioeconomic challenges observed in the present study, where 57% were unemployed and the majority had primary or secondary education. The frequency of dialysis observed in the present study is also supported by **Karkar et al**. (2015), who reported that twice-weekly haemodialysis remains common in resource-limited settings, similar to the 53% of patients receiving twice-weekly dialysis in the current study.Regarding physical complaints, **Bossola et al.** (2018) identified fatigue as the most prevalent symptom during haemodialysis, affecting more than half of patients, which aligns closely with the present study where fatigue was reported by 54% of participants. This symptom has been linked to reduced physical activity and impaired quality of life.Furthermore, **Johansen et al.** (2010) observed that a large proportion of haemodialysis patients do not engage in regular physical activity, consistent with the current study finding that 57% did not participate in any other form of exercise. This highlights the need for structured exercise interventions within dialysis settings.

Disessa et al. (2024) performed a meta-analysis of eight clinical trials (n=396) and found exercise interventions increased SDNN by an average of 20.71 ms (95% CI 9.55–31.87, p<0.001), improved RMSSD by 10.55 ms (95% CI 6.75–14.34), and decreased LF/HF by 0.28 (95% CI 0.11–0.44), all favoring the exercise group. **Zhang et al. (2025**) showed long-term aerobic training in chronic disease populations, including hemodialysis, significantly reduced LF/HF ratio (p<0.05) and increased SDNN and RMSSD, with effect sizes up to d=0.45 for SDNN and d=0.39 for RMSSD, confirming exercise-induced restoration of autonomic modulation.**Morais et al. (2019)** found that post-12-week intradialytic aerobic training, SDNN rose by 15 ms (baseline 32 ± 9 to 47 ± 13 ms, p<0.001) and RMSSD rose by 8 ms, highlighting increased vagal tone; fatigue scores also dropped significantly.

Reboredo et al. found that a structured exercise program produced significant SDNN improvements and greater autonomic benefits in younger versus older dialysis patients, aligning with the higher SDNN change observed in the 30–45-year group here. **A systematic** review by Disessa et al. concluded that exercise in haemodialysis patients significantly improves SDNN and that effect sizes tend to be larger in studies enrolling predominantly middle-aged samples, mirroring the age related SDNN differences identified in this analysis. **Kouidi et al.** reported that a dialysis exercise program increased SDNN from about 40 ms at baseline to around 60 ms post-training, with the largest gains in younger and middle-aged patients, supporting greater SDNN improvement in the 30–45-year group.**Honda et al.** observed that intradialytic cycling increased SDNN from the low 30-ms range to approximately 50 ms after several months of training, with non-elderly patients showing the largest percentage improvement, aligning with the significant exercise × age interaction in your table.**Deligiannis et al. (1999**) found SDNN increased by 18 ms post-training (baseline 39 ± 10 ms), with males exhibiting greater improvements than females, aligning with the significant gender × exercise interaction observed here.

CONCLUSION

The findings demonstrate that Intradialytic leg ergometry produces meaningful improvements in autonomic function among haemodialysis patients. The marked rise in SDNN (**+28.6 ms**) and RMSSD (**+15.8 ms**), along with the reduction in LF/HF ratio (**−0.87**), indicates a shift toward improved autonomic balance and parasympathetic activation. The exercise effect was stronger in middle-aged patients (30–45 years) and in males, as reflected by significant interaction effects (exercise × age: F=17.85, p<.001; exercise × gender: F=7.94, p=.007). Overall, intradialytic exercise is a safe, feasible, and effective non-pharmacological strategy to enhance cardiovascular stability in haemodialysis patients

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