

Standard Heart Rate Recovery Metrics After Chester Step Test in Sedentary Youth: A Cross-Sectional Study

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Abstract—Heart rate recovery (HRR) after exercise is a simple, non-invasive indicator of cardiac autonomic recovery, but reference data following the Chester Step Test (CST) in sedentary young adults are limited. This cross-sectional study at Ojas College of Physiotherapy, Jalna, India, recruited 351 sedentary adults aged 18–29 years (181 males, 170 females; mean age 20.9 ± 1.7 years) by convenience sampling; all had low physical activity on the International Physical Activity Questionnaire–Short Form (IPAQ-SF). Participants performed a 30-cm, metronome-paced CST starting at 15 steps/min and increasing by 5 steps/min every 2 min. HRR was calculated as peak post-exercise heart rate minus heart rate at 30 s and at 1, 3, 6, 9 and 12 min. Mean heart rate rose from 74.2 ± 4.5 to 166.1 ± 7.1 bpm. Mean HRR was 7.3 ± 2.0 bpm at 30 s, 17.5 ± 3.4 bpm at 1 min, 41.3 ± 5.0 bpm at 3 min, 88.3 ± 9.2 bpm at 6 min, 91.5 ± 8.4 bpm at 9 min and 91.9 ± 8.3 bpm at 12 min, indicating rapid early recovery and a plateau by about 6 min. Fifteen participants (4.3%) had a 1-min HRR below 12 bpm, and heart rate returned to baseline in a mean of 6.5 ± 1.6 min. HRR did not differ significantly by gender and was not significantly correlated with body mass index, age or physical activity. These preliminary, protocol-specific values support multi-point HRR monitoring in cardiopulmonary physiotherapy and need validation in larger multi-centre samples.

Index Terms—Autonomic nervous system, Cardiopulmonary physiotherapy, Chester Step Test, Heart rate recovery, Sedentary behaviour, young adults.

I. INTRODUCTION

Physical inactivity among young people is a major public health concern, and low cardiorespiratory fitness in youth is a recognised marker of poorer present and future cardiometabolic health [27], [31]. Prolonged sedentary behaviour and lack of exercise

are linked to chronic disease, partly through adverse effects on autonomic regulation of the heart [38].

Heart rate recovery (HRR) is the fall in heart rate from its peak at the end of exercise to a given time-point during recovery. The early fall is mainly due to rapid reactivation of cardiac vagal (parasympathetic) activity, followed by a slower phase involving sympathetic withdrawal and metabolite clearance [19], [37]. A blunted 1-min HRR (a fall of 12 beats per minute or less after symptom-limited treadmill exercise) predicted all-cause mortality in a large clinical cohort [52]. Most HRR research, however, has used maximal treadmill or cycle tests in middle-aged or clinical populations, and little is known about HRR in healthy sedentary young adults.

Cardiopulmonary exercise testing with gas analysis is the reference method of assessing fitness but is costly and needs specialised staff, so submaximal field tests are widely used [46]. The Chester Step Test (CST) is a progressive, multi-stage, metronome-paced submaximal test that needs only an adjustable step, an audio pacer and a heart rate monitor, and has shown good validity and reliability for estimating aerobic capacity [50], [51]. The CST is normally used to predict maximal oxygen uptake from exercise heart rates, so the information in its recovery phase is seldom used. Reference values for HRR after the CST in sedentary young adults, particularly in India, are lacking.

The aim of this study was therefore to describe HRR and recovery kinetics at 30 s and at 1, 3, 6, 9 and 12 min, and the time taken to return to baseline heart rate, after the CST in sedentary young adults aged 18–29 years, and to examine their relationship with gender, body mass index (BMI), age and physical activity level.

II. MATERIALS AND METHODS

A. Study Design and Participants

A cross-sectional observational study was carried out over six months at Ojas College of Physiotherapy, Jalna, Maharashtra, India. Participants were recruited by convenience sampling. The sample size was calculated with the formula for estimating a proportion, $n = Z^2pq/d^2$, using $Z = 1.96$, $p = q = 0.50$ and absolute precision $d = 0.0523$, giving $n \approx 350.7$, rounded to 351.

Eligible participants were men and women aged 18–29 years classified as having low physical activity on the IPAQ-SF [53], able to understand instructions and perform the test safely, and willing to give written informed consent. Those with known cardiovascular or respiratory disease, a current respiratory infection, smoking, pregnancy, use of medication known to affect heart rate, or any condition making exercise testing unsafe were excluded. Permission was obtained from the institution, and participants were told that participation was voluntary and their data confidential.

B. Materials

The following were used: a 30-cm step platform, a metronome application for audio pacing, a pulse oximeter, a blood pressure apparatus, the Borg Rating of Perceived Exertion (RPE) scale (6–20) [54], the IPAQ-SF, a stopwatch and a data collection sheet (Fig. 1).



Fig. 1. Equipment used: (a) blood pressure apparatus and pulse oximeter, (b) 30-cm step platform, (c) metronome application for pacing.

C. Procedure

After screening and consent, age, gender and medical history were recorded and BMI was measured. Physical activity over the previous seven days was recorded with the IPAQ-SF and expressed as MET-min/week; all participants fell in the low category (below 600 MET-min/week). After a rest period, resting heart rate (HR), blood pressure (BP), oxygen saturation (SpO_2), respiratory rate (RR) and RPE were recorded.

Each participant then performed the CST on the 30-cm step, paced by the metronome, at 15 steps/min for the first 2 min, increasing by 5 steps/min every 2 min [50]. The test was stopped when the participant reached about 80% of predicted maximal heart rate, developed moderate exertion or symptoms, could not keep to the cadence, or when safety required. Participants were observed throughout and the test was stopped for dizziness, chest discomfort, severe breathlessness, marked fatigue or any other concerning symptom. Peak HR and the other post-exercise measures were recorded immediately after stopping, and HR was then recorded at 30 s and at 1, 3, 6, 9 and 12 min of recovery. The time taken for HR to return to the individual's resting value was also noted.



Fig. 2. A participant performing the Chester Step Test under supervision.

D. Outcome Calculation

HRR at each time-point was calculated as

$$HRR_t = HR_{peak} - HR_t \quad (1)$$

where HR_{peak} is the immediate post-exercise heart rate and HR_t is the heart rate at recovery time t . HRR at 1, 3 and 6 min is written HRR_1 , HRR_3 and HRR_6 . The percentage of heart rate reserve recovered at 1 min was

$$\%HRR_1 = [(HR_{peak} - HR_1) / (HR_{peak} - HR_{rest})] \times 100 \quad (2)$$

An HRR_1 below 12 bpm was taken as the abnormal cut-off [52]. Mean arterial pressure (MAP), pulse

pressure (PP) and rate–pressure product (RPP) was derived from the recorded BP and HR using standard formulae.

E. Statistical Analysis

Data were entered in Microsoft Excel. Continuous variables are given as mean $\pm$ standard deviation (SD) or median (interquartile range, IQR), and categorical variables as numbers and percentages. The Shapiro–Wilk test was applied to HRR₁ ($W = 0.988$, $p = 0.014$); because of the large sample ($N = 351$) and a near-symmetric distribution, parametric tests were used. Pre- and post-test values were compared by the paired t-test, males and females by the independent-samples t-test with Welch correction, associations of BMI, MET-min/week and age with HRR by Pearson's correlation coefficient (r), and HRR₁ across BMI categories by one-way ANOVA. A two-tailed p-value below 0.05 was considered significant.

III. RESULTS

A. Participant Characteristics

The study included 351 participants (181 males, 51.6%; 170 females, 48.4%) with a mean age of 20.9 ± 1.7 years (range 18–29 years). Mean BMI was 22.1 ± 2.9 kg/m² (range 14.4–30.5); 257 participants (73.2%) were of normal weight, 52 (14.8%) overweight, 39 (11.1%) underweight and 3 (0.9%) obese. Mean physical activity was 229.2 ± 79.1 MET-min/week (range 99–450), and all participants were in the low IPAQ-SF category.

B. Response to the Chester Step Test

The CST produced significant changes in every parameter ($p < 0.001$; Table I). Mean heart rate rose from 74.2 ± 4.5 to 166.1 ± 7.1 bpm and systolic BP from 118.3 ± 4.9 to 143.8 ± 6.2 mmHg, with smaller rises in diastolic BP, MAP, PP, RR and RPE. SpO₂ fell slightly from $97.5 \pm 0.9\%$ to $95.6 \pm 0.9\%$.

Table I
Pre-Test And Post-Test Parameters (Mean $\pm$ Sd)
With Paired T-Test ($N = 351$)

Parameter	Pre-test	Post-test	t	p
Heart rate (bpm)	74.2 ± 4.5	166.1 ± 7.1	207.81	<0.001*
Systolic BP (mmHg)	118.3 ± 4.9	143.8 ± 6.2	125.28	<0.001*
Diastolic BP (mmHg)	75.3 ± 4.0	78.9 ± 4.4	33.53	<0.001*

MAP (mmHg)	89.7 ± 3.1	100.5 ± 3.6	111.63	<0.001*
Pulse pressure (mmHg)	43.0 ± 6.2	64.9 ± 7.5	95.38	<0.001*
RPP ($\times 100$)	87.9 ± 6.5	238.9 ± 14.5	203.96	<0.001*
SpO ₂ (%)	97.5 ± 0.9	95.6 ± 0.9	-28.98	<0.001*
RR (breaths/min)	15.3 ± 1.9	24.4 ± 2.5	55.58	<0.001*
RPE (Borg 6–20)	6.0 ± 0.0	15.6 ± 1.5	120.84	<0.001*

* $p < 0.05$, paired t-test, two-tailed. BP = blood pressure; MAP = mean arterial pressure; RPP = rate–pressure product; RR = respiratory rate; RPE = rating of perceived exertion.

C. Heart Rate Recovery

Heart rate fell progressively after exercise (Table II, Fig. 3). Mean HRR was 17.5 ± 3.4 bpm at 1 min, 41.3 ± 5.0 bpm at 3 min and 88.3 ± 9.2 bpm at 6 min, after which it changed little (91.5 ± 8.4 bpm at 9 min and 91.9 ± 8.3 bpm at 12 min). On average, $19.2 \pm 4.2\%$ of the exercising heart rate reserve was recovered in the first minute.

Table II
Heart Rate Recovery at Successive Time-Points ($N = 351$)

Time-point	HRR (mean $\pm$ SD, bpm)	Median (IQR)	Range
30 s	7.3 ± 2.0	7.0 (6.0–9.0)	0–14
1 min	17.5 ± 3.4	17.0 (15.0–20.0)	6–27
3 min	41.3 ± 5.0	41.0 (38.0–44.5)	25–57
6 min	88.3 ± 9.2	88.0 (82.0–95.0)	60–115
9 min	91.5 ± 8.4	92.0 (86.0–97.0)	67–115
12 min	91.9 ± 8.3	92.0 (86.0–97.0)	68–115

HRR = peak post-exercise heart rate minus heart rate at the time-point; IQR = interquartile range.

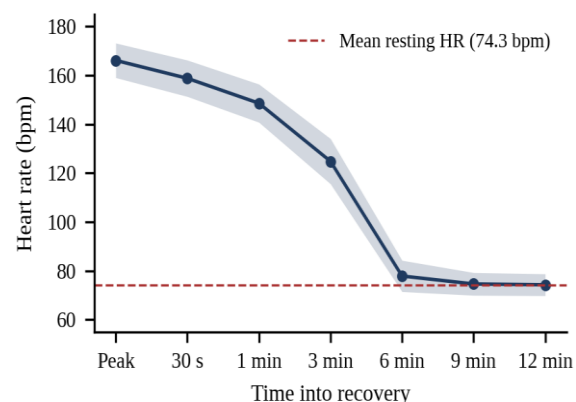


Fig. 3. Heart rate during recovery after the CST (mean $\pm$ SD).

Fifteen of 351 participants (4.3%) had an HRR₁ below 12 bpm, while 336 (95.7%) were at or above it. The mean time to return to baseline heart rate was 6.5 ± 1.6 min (median 6.0, IQR 5.0–7.0), and most participants returned to baseline within about 6–9 min.

D. Gender Comparison

Males had a significantly higher BMI than females ($p < 0.001$) and females were slightly older ($p = 0.028$). There were no significant gender differences in resting or peak HR, HRR₁, HRR₃, HRR₆, time to baseline, systolic BP or RPP (all $p > 0.05$; Table III).

Table III
Gender-Wise Comparison of Key Variables
(Independent T-Test)

Variable	Male (n = 181)	Female (n = 170)	t	p
Age (years)	20.7 ± 1.8	21.1 ± 1.5	-2.21	0.028*
BMI (kg/m ²)	22.8 ± 2.6	21.4 ± 3.0	4.67	<0.001*
MET-min/week	231.7 ± 73.6	226.5 ± 84.6	0.61	0.543
Resting HR (bpm)	74.2 ± 4.5	74.3 ± 4.4	-0.06	0.955
Peak HR (bpm)	165.9 ± 7.1	166.3 ± 7.0	-0.54	0.590
HRR ₁ (bpm)	17.4 ± 3.4	17.7 ± 3.4	-0.81	0.420
HRR ₃ (bpm)	41.5 ± 5.3	41.1 ± 4.6	0.81	0.417
HRR ₆ (bpm)	88.0 ± 9.3	88.6 ± 9.2	-0.54	0.590
Time to baseline (min)	6.4 ± 1.6	6.5 ± 1.5	-1.00	0.316
Resting SBP (mmHg)	118.3 ± 4.8	118.4 ± 5.1	-0.04	0.967
Peak SBP (mmHg)	143.8 ± 6.0	143.7 ± 6.3	0.18	0.859
Resting RPP ($\times 100$)	87.8 ± 6.5	87.9 ± 6.5	-0.07	0.945
Peak RPP ($\times 100$)	238.7 ± 14.4	239.1 ± 14.7	-0.25	0.801

* $p < 0.05$. SBP = systolic blood pressure; RPP = rate–pressure product.

E. Association with BMI, Physical Activity and Age
BMI, MET-min/week and age showed no significant correlation with HRR₁, HRR₃, HRR₆ or time to baseline (all $p > 0.05$; Table IV). Physical activity had only a weak, non-significant inverse trend with HRR₁ ($r = -0.095$, $p = 0.074$). One-way ANOVA showed no significant difference in HRR₁ across BMI categories ($F = 0.228$, $p = 0.877$; Table V); the obese group had only three participants.

Table IV
Pearson Correlation of Bmi, Physical Activity and Age with Hrr, R (P)

Variable	BMI	MET-min/week	Age
HRR ₁ (bpm)	0.030 (0.575)	-0.095 (0.074)	0.019 (0.718)
HRR ₃ (bpm)	0.029 (0.585)	-0.091 (0.088)	0.023 (0.664)
HRR ₆ (bpm)	0.015 (0.774)	-0.075 (0.162)	0.012 (0.821)
Time to baseline (min)	-0.086 (0.109)	-0.023 (0.671)	-0.079 (0.141)

r = Pearson correlation coefficient; no correlation was significant at $p < 0.05$.

Table V
One-Way Anova of Hrr1 Across Bmi Categories

BMI category	n	HRR ₁ (mean $\pm$ SD, bpm)
Underweight	39	17.3 ± 3.0
Normal	257	17.5 ± 3.5
Overweight	52	17.8 ± 3.4
Obese	3	18.3 ± 3.2

$F = 0.228$, $p = 0.877$.

IV. DISCUSSION

This study describes HRR after the CST in 351 sedentary young adults. Heart rate fell progressively, rapidly in the first minutes and approaching a plateau by about 6 min. This is consistent with the established pattern of early vagal reactivation followed by a slower phase of sympathetic withdrawal [19], [55]. Mean HRR₁ was 17.5 ± 3.4 bpm and only 4.3% of participants were below 12 bpm. This should not be read as showing that sedentary behaviour is harmless: a young, apparently healthy sample may show preserved short-term autonomic recovery despite low reported activity. The 12-bpm cut-off came from symptom-limited treadmill testing in a clinical population [52] and may not transfer to passive recovery after submaximal stepping in young adults, so the present values are better regarded as descriptive reference data than as diagnostic thresholds. Studies in sedentary young adults have linked low activity with blunted early vagal reactivation [11], [12], [14], whereas most of the present cohort recovered above the cut-off, which may reflect the narrow, uniformly low activity range and the submaximal workload. The CST imposed a substantial but safe load, with significant rises in HR, BP, RR and RPE and only a

small fall in SpO₂, in keeping with the intended submaximal design [50], [51]. HRR did not differ between males and females, so gender alone may not be a major determinant of HRR within this narrow age range, even though BMI and age differed between the groups.

The absence of correlation with BMI and physical activity should be interpreted with caution. All participants were in the low-activity band, so the restricted range of MET-min/week may have weakened any association; the IPAQ-SF is self-reported and has only modest criterion validity [53]; and only three participants were obese. The results should not be generalised to populations with higher adiposity or to physically active people. Overall, the main value of the data is the full recovery trajectory rather than a single cut-off, which supports routine multi-point HRR recording after the CST in cardiopulmonary physiotherapy.

V. LIMITATIONS

The cross-sectional design cannot establish causal relationships. Sampling was by convenience at a single institution, limiting generalisability. Physical activity was self-reported, all participants were in the low IPAQ-SF category, there was no physically active comparison group, and the obese subgroup was very small. HRR at 2 min was not recorded and therefore could not be analysed.

VI. PUBLICATION PRINCIPLES

This paper has been prepared in line with the publication principles of the journal. The following points describe how the present work addresses them.

- 1) Advancing knowledge and citing prior work. The study provides descriptive reference data on multi-point heart rate recovery after the Chester Step Test in sedentary young adults, a population for which such data are scarce, and it builds on earlier validation and prognostic work on the test and on heart rate recovery [50], [51], [52].
- 2) Length appropriate to the work. The paper reports a single-centre cross-sectional study of 351 participants. Only the tables and the single recovery graph needed to present the main findings are included; the full participant-level master chart, consent form and data collection

sheet are in the source dissertation (Annexures D and F).

- 3) Scientific and technical merit. The sample size was calculated a priori, standard instruments and a validated test protocol were used, and appropriate parametric tests were applied. Because the findings are protocol- and population-specific, they are described as preliminary, and the limitations are stated openly rather than claiming universal normative values.
- 4) Information sufficient for replication. The step height, cadence progression, termination criteria, recovery time-points, outcome formulae (1) and (2), inclusion and exclusion criteria and statistical methods are all reported, so that other investigators can repeat the procedure and compare their results with the values given here.

VII. CONCLUSION

In 351 sedentary young adults, heart rate fell consistently after the Chester Step Test, with mean HRR rising from 7.3 bpm at 30 s to 17.5 bpm at 1 min, 41.3 bpm at 3 min and about 88–92 bpm from 6 to 12 min. Heart rate returned to the individual baseline in a mean of 6.5 ± 1.6 min (generally within 6–9 min). Only 4.3% had HRR₁ below 12 bpm, and HRR was not significantly related to gender, BMI, age or self-reported physical activity. These preliminary, protocol-specific values show that multi-point HRR assessment after the CST is feasible and low-cost. Larger multi-centre studies with objective activity measurement, active comparison groups and adequate representation of obese participants are needed to establish age- and sex-specific reference ranges.

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