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Citation:

Mellis, MG and Ingle, L and Carroll, S (2014) Variability in heart rate recovery measurements over 1 year in healthy, middle-aged adults. *International journal of sports medicine*, 35 (2). 135 - 138. ISSN 0172-4622 DOI: <https://doi.org/10.1055/s-0033-1349091>

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**Variability in Heart Rate Recovery Measurements Over 1 Year in Healthy, Middle-Aged Adults**

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**Abstract**

This study assessed the longer-term (12-month) variability in post-exercise heart rate recovery following a submaximal exercise test. Longitudinal data was analysed for 97 healthy middle-aged adults (74 male, 23 female) from two occasions, 12 months apart. Participants were retrospectively selected if they had stable physical activity habits, submaximal treadmill fitness and anthropometric measurements between the two assessment visits. A submaximal Bruce treadmill test was performed to at least 85% age-predicted maximum heart rate. Absolute heart rate and  $\Delta$  heart rate recovery (change from peak exercise heart rate) were recorded for one and two minutes post-exercise in an immediate supine position. Heart rate recovery at both time-points was shown to be reliable with intra-class correlation coefficient values  $\geq 0.714$ . Absolute heart rate one-minute post-exercise showed the strongest agreement between repeat tests ( $r=0.867$ ,  $P<0.001$ ). Lower coefficient of variation ( $\leq 10.2\%$ ) and narrower limits of agreement were found for actual heart rate values rather than  $\Delta$  heart rate recovery, and for one-minute rather than two-minute post-exercise recovery time points. Log-transformed values generated better variability with acceptable coefficient of variation for all measures (2.2 – 10%). Overall, one minute post-exercise heart rate recovery data had least variability over the 12-month period in apparently healthy middle-aged adults.

**Key Words:** Variability; Intra-class correlation coefficients; Limits of agreement; Coefficient of variation.

## **Introduction**

Post-exercise heart rate recovery (HRR) is not always recorded or monitored following exercise testing, this is despite the well-established associations of slow HRR with training status [10], cardiovascular disease (CVD) risk and mortality [8, 9, 19]. HRR has also been reported to be modified by the *CHRM2* gene in sedentary and trained individuals [13]. HRR as a supplementary mode of cardiovascular assessment requires good reproducibility to be implemented in routine screening procedures that track longitudinal changes in CVD risk. Few investigations have reported the reproducibility and reliability of HRR, and of these they have been based on short-term test-retest durations from day-to-day variation [16, 17], 72 hours [4], two weeks [2], with the longest follow-up of 18 weeks [21]. However, cardiovascular screening in healthy adults attending preventative health assessments is typically undertaken on an annual basis and no study to date has assessed longer-term reproducibility.

Various factors identified by Morise [18] can influence the reliability of HRR including exercise protocol and intensity (influencing peak HR attained) and the post-exercise recovery protocol which may incorporate a cool down or immediate cessation, and various postural differences thereafter including supine, seated or upright, all of which will affect the rate of HR decline. Furthermore, the post-exercise HRR monitoring time-points have varied from 30 seconds [8, 15] to eight minutes [11]. Most recently, it has been suggested HRR is more reliable following submaximal exercise testing and longer recovery durations [2, 4]. HRR after submaximal exercise has been previously reported to show high intra-class correlation coefficient (ICC) values, for exercise protocols above 65% of age-predicted maximum heart rate (APMHR), but highest values with protocols requiring at least 80% APMHR in healthy

individuals [2]. However, other investigators found no difference in HRR reliability following submaximal and supramaximal exercise [1]. A recent review supports the use of HRR as a valuable tool to monitor changes in training status in athletes and less trained individuals, which would also encompass clinical populations, but they highlighted the need for the standardisation of HRR protocols [10].

Thus, the aim of this study was to assess the longitudinal variation of post-submaximal exercise (85% APMHR) HRR after 12-month follow up in healthy middle-aged adults attending a preventative health assessment.

## **Methods and Materials**

Participants: Longitudinal data was retrospectively collected for 97 (74 male, 23 female) participants that had attended two health assessments, 12 months apart ( $47.5 \pm 7.1$  years and  $48.6 \pm 7.2$  years, test 1 and 2 respectively). Participants were instructed to not consume any food or caffeine within 12 hours before the tests and to not perform any exercise within 24 hours of the test [20]. The participants for this study were retrospectively selected based on the following main criteria; no change in frequency of physical activity determined by self-report questionnaire (total, moderate and vigorous). To ensure similar training and lifestyle status, the secondary criteria included the following; 1) unchanged smoking status 2) self-report alcohol intake within 5 units, 3) body mass within 2.0kg or less than 1% body mass and 4) exercise test duration was within 10% of previous test result. There was no control for dietary changes so mean values for lipid profile and glucose were reported in addition to anthropometric measurements at baseline and 12-month follow up. Permission for data collection and ethical approval was granted by Carnegie Faculty ethics committee, Leeds

Metropolitan University. Research was conducted ethically according to international standards and meets the ethical standards of this journal [12]

**Preventive Health assessment:** Prior to the exercise test, each participant was involved in a assessment to establish individual CVD risk factors. Fasting venous blood samples were collected and analysed on-site using a Piccolo analyser (Abaxis, USA). Lipid profile and blood glucose results are reported for the purpose of the present investigation. Resting blood pressure (BP) was recorded automatically (Tango BP monitor, Suntech Medical, Oxfordshire, UK) following 5-minute quiet rest. Anthropometry was measured by body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and body fat content (BF%) determined by whole-body bioelectrical impedance (Bodystat Limited, UK).

**Exercise test and HRR protocol:** Each participant performed a submaximal Bruce treadmill test [5] to at least 85% APMHR using a T2100 treadmill (GE Healthcare, UK). The time taken to achieve target HR was used as the surrogate measure of cardiorespiratory fitness. A 12-lead electrocardiograph (ECG) was monitored before the test to determine resting HR (RHR), throughout the test and during recovery (Marquette CASE Stress system, GE Healthcare, UK). HR was recorded at the end of each minute and blood pressure (BP) was recorded in the last minute of each 3-minute stage (Tango BP monitor, Suntech Medical, Oxfordshire, UK). Once target HR had been achieved the treadmill was stopped and participants adopted an immediate supine position to promote parasympathetic activation for a minimum of five minutes or until returned to resting level [5]. HRR was recorded at the end of each minute, both as an absolute HR value, for example, 120 b.min<sup>-1</sup> [17], and as a  $\Delta$ HRR value (peak HR minus HR at selected the time-point) for example, 20 beats. It has been suggested the absolute HR value produces greater reliability than  $\Delta$ HRR, so both measures

were used in this study [4]. For a more accurate HRR measurement, training status and final exercise workload should be stabilised. To improve test sensitivity to detect meaningful changes in HRR, an exercise intensity between 86-93% of APMHR should be used [17]. Absolute HR at one and two minutes post-exercise are henceforth referred to as  $HRR_{60}$  and  $HRR_{120}$ , respectively, and  $\Delta HRR$  at one and two minutes is referred to as  $\Delta HRR_{60}$  and  $\Delta HRR_{120}$ , respectively.

Statistical analysis: Microsoft Excel 2010 and SPSS statistical software (Version 19.0) was used for all analysis. Standard statistical methods were used to calculate the means and standard deviations. Normal distribution and homogeneity of variance were verified by Kolmogorov-Smirnov and Levene's tests. Students paired t-tests were performed to determine any differences between HRR at baseline and follow-up. ICC's were performed to determine absolute agreement between baseline and the follow up HRR results. There is currently no consensus for exact ICC classifications, but the level of agreement was classified as moderate if 0.6-0.75; good if 0.75-0.9 and excellent if  $>0.9$  in this study [3].

Coefficient of variation (CoV), bias and 95% limits of agreement (LOA) were calculated to determine the within-subject variation of all HRR measures using raw and log-transformed values. To calculate within-subject CoV, within-subject standard deviation ( $SD_i$ ) was divided by the group mean, this was multiplied by 100 to obtain a percentage score (CoV%). The data was analysed using Bland-Altman 95% LOA, by the formula  $\bar{x} \pm (\text{critical value of } t * SD)$  where  $\bar{x}$  = mean bias (mean of the differences), and  $SD$  = standard deviation of the differences [12]. In this study, the sample size was 97 participants ( $df = 96$ ). From standard statistical tables, the two-tailed critical value of  $t$  for 96  $df$  at the 95% confidence level was 1.988. All statistical analyses for CoV% and LOA were performed using Microsoft Excel

2010; ICC and t-tests were performed using SPSS Version 19.0. An *alpha* level of  $P \leq 0.05$  was accepted as significant for all statistical analyses.

## **Results**

**Descriptives:** All data were normally distributed. Preliminary Student's paired t-tests revealed that there was no significant differences from baseline to follow-up for BMI, WC, WHR, BF%, exercise duration to target HR (85% APMHR), weekly frequency of total, moderate and vigorous physical activity (all  $P > 0.05$ ). In addition, lipid profile and fasting blood glucose levels were not significantly different between the two testing occasions ( $P > 0.05$ ). Table 1 shows HRR values were not different between tests, for absolute values ( $P = 0.103$  and  $P = 0.653$ ,  $HRR_{60}$  and  $HRR_{120}$  respectively) and  $\Delta HRR$  values ( $P = 0.371$  and  $P = 0.106$ ,  $\Delta HRR_{60}$  and  $\Delta HRR_{120}$  respectively). These findings were evident despite a small difference in the peak HR between tests (mean difference  $2.25 \text{ b}\cdot\text{min}^{-1}$ ,  $P < 0.001$ ).

**HRR reproducibility:** The ICC values presented in table 2 were reasonably high for both measures of HRR, at both time-points following submaximal exercise to  $89.2 \pm 4.1\%$  and  $88.5 \pm 4.1\%$  of APMHR, year 1 and 2 respectively. According to ICC, both HRR time-points show a good agreement between the same variables measured 12 months apart, with  $HRR_{60}$  slightly greater than  $HRR_{120}$ . The absolute HRR ICC values were higher with narrower confidence intervals than  $\Delta HRR$ . The 95% confidence levels were similar between time-points. These data would suggest absolute HR is more reliable than  $\Delta HRR$  based on ICC.

Raw HRR data is presented in table 3. Despite data being normally distributed, the raw data produced large CoV%, particularly for  $\Delta HRR$  data so log transformed values are presented in brackets. The raw HRR data showed higher CoV% than the log-transformed data, although



untransformed HRR showed reasonable agreement between measurements, particularly HRR<sub>60</sub> at 10.2%. With the log-transformed data, the lowest CoV% occurred with HRR<sub>60</sub> at 2.2% ( $4.81 \pm 0.11$ ), followed by HRR<sub>120</sub> at 2.9% ( $4.56 \pm 0.13$ ), suggesting excellent agreement. The highest CoV% was displayed for  $\Delta$ HRR<sub>60</sub> data where a mean value of 10% was recorded ( $3.32 \pm 0.34$ ). Both  $\Delta$ HRR variables showed  $\text{CoV} \leq 10\%$  which suggests acceptable agreement compared to the untransformed CoV%.

LOA for  $\Delta$ HRR<sub>120</sub> ( $-1.83 \pm 21.35$ ) displayed the largest variability, indicating a 95% confidence interval of  $33.16 \text{ b}\cdot\text{min}^{-1}$  ( $56.34 - 23.18$ ) to  $75.86 \text{ b}\cdot\text{min}^{-1}$  ( $56.34 + 19.52$ ). The HRR<sub>60</sub> displayed the lowest variability ( $-1.43 \pm 17.23$ ) indicating a 95% confidence interval from  $105.23 \text{ b}\cdot\text{min}^{-1}$  ( $123.89 - 18.66$ ) to  $139.69 \text{ b}\cdot\text{min}^{-1}$  ( $123.89 + 15.8$ ), illustrated in Figure 1. These LOA data are not narrow ranges expected for excellent agreement and the  $\Delta$ HRR data do not corroborate with CoV% data. LOA and CoV% for log-transformed HRR data (not presented) suggested there was less variability at  $\Delta$ HRR<sub>120</sub> than  $\Delta$ HRR<sub>60</sub>, which is inconsistent with absolute HRR findings. The 5% difference suggested  $\Delta$ HRR<sub>120</sub> is a more reliable time-point for test-retest reliability in middle-aged healthy adults following a submaximal treadmill test when using log-transformed data and  $\Delta$ HRR.

## **Discussion**

The current study has demonstrated that following repeat submaximal treadmill tests, performed 12 months apart, absolute HRR<sub>60</sub> data displayed variability of 10.2%. The log-transformed absolute HRR<sub>60</sub> and HRR<sub>120</sub> displayed variability of 2.2% and 2.9% respectively. The lower variability at one-minute post-exercise compared to two-minutes is similar to Lamberts *et al.* [16]. These findings indicate that the utilisation of simple post-exercise HRR

recordings to measure cardiac autonomic function after submaximal exercise were reliable in healthy, middle-aged adults. These findings are based on apparently healthy adults who made no notable changes to their physical activity habits and exhibited similar fitness and anthropometric measurements. This was further supported by good ICC values  $\geq 0.711$  for both time-points, with the highest for  $HRR_{60}$ . The mean peak HR of 88-89% in this study supports the findings of Arduini, Gomez-Cabera and Romagnoli [2] which reported a high mean ICC of 0.827 and low standard error of measurement for HRR after submaximal exercise, (particularly after 80% APMHR compared to 65% APMHR). The current study would suggest higher ICC reliability can be reported between 85-90% APMHR in healthy individuals.

The CoV% and ICC findings suggested a higher level of agreement with  $HRR_{60}$  compared to  $HRR_{120}$ , which supports the findings of Lamberts and colleagues [16], who reported CoV for one-minute HRR to be more reliable (2.4%) than two-minutes (6.1%) after submaximal running exercise to around 90% APMHR. Al Haddad and colleagues [1] found similar reliability of  $\Delta HRR$  to this study at 15-32% but current  $\Delta HRR$  data is consistent with previous studies that have consistently concluded improved reliability of  $\Delta HRR$  with longer recovery durations [2, 4]. Most HRR studies focus on the delta change from peak exercise HR as this is the method implemented to identify abnormal HRR (for example HRR of <12 beats) and has been used since the late 1990's [8]. However, the results still support the use of absolute HRR values over  $\Delta HRR$  due to narrower LOA ranges and CoV below 5% indicating less variability, which postulates higher reliability [4]. This is a simple addition to exercise testing protocols - and the test administrator can refer and report the exact heart rate values at recovery time points and no calculations are required. We also recommend the use

of  $\Delta$ HRR for comparative purposes - given this is related to CVD risk within the majority of published studies.

HRR reliability studies have implemented similar continuous graded treadmill tests [8, 16, 17, 19, 21], some with supine recovery [19, 21]; whilst cycle ergometry [2], cool-down [8] and seated HRR protocols have been used by others [2, 4, 9]. Supine recovery was favoured for the current study as it has been shown to accelerate and increase parasympathetic reactivation following submaximal exercise [6]. Previous studies have only administered short test-retest durations between measurements [2, 4, 21]. It may be the case that short-term reliability improves with duration, but longer-term reliability does not. This is the first study to assess HRR reliability over a 12-month period, which suggests  $HRR_{60}$  is more reliable than  $HRR_{120}$  over longer test-retest conditions when the absolute HRR values are used (due to lower variability). This may be suggestive that the parasympathetic reactivation associated with  $HRR_{60}$  is more stable over time than the sympathetic influences of longer recovery durations.

The same submaximal exercise protocol, immediate supine HRR protocol and HRR time-points were controlled for but other factors may have influenced the reliability within this investigation. The participants selected had no or minimal changes to their physical activity habits, fitness and anthropometric measurements in order to control for biological error, but minor differences may have contributed to the variability of data. The exact control of extraneous variables could not be guaranteed with a 12-month time period between measurements, therefore this may affect the reliability of the data. For example, the time of day could not be controlled so participants may have been tested in the afternoon, after a stressful morning at work, leading to temporary elevated sympathetic activity and reduced

parasympathetic activity. Finally, reliability was higher for log-transformed data with narrow LOA ranges and smaller CoV% values in comparison to absolute HRR data but it is best to report and monitor the absolute data when informing participants of their results. It should also be noted that future work should consider expressing absolute and relative values for HRR measurements [17].

### **Conclusion**

The HRR data was reliable over the 12-month period in healthy middle-aged adults who had made no changes to self-reported frequency of physical activity, and with only minimal changes to their fitness and anthropometric profiles. Absolute HRR appears more reliable than  $\Delta$ HRR according to all measures of reliability. HRR reliability does not improve with post exercise monitoring duration, following a 12-month follow-up, as first-minute recovery values were more reliable when absolute HRR is recorded. It is conceivable that the parasympathetic reactivation in the first minute is more stable over time than the sympathetic mechanisms associated with longer duration post-exercise recovery.

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Table 1: Heart rate recovery results for both occasions (Mean  $\pm$  SD).

<b>Variable</b>	<b>Baseline</b>	<b>12-month follow up</b>	<b><i>P</i>-value</b>
<b>HRR<sub>60</sub></b> (b.min <sup>-1</sup> )	124.6 $\pm$ 13.2	123.1 $\pm$ 11.9	0.103
<b>HRR<sub>120</sub></b> (b.min <sup>-1</sup> )	96.9 $\pm$ 12.9	96.5 $\pm$ 11.8	0.653
<b><math>\Delta</math>HRR<sub>60</sub></b> (beats)	29.3 $\pm$ 9.8	28.5 $\pm$ 9.2	0.371
<b><math>\Delta</math>HRR<sub>120</sub></b> (beats)	57.0 $\pm$ 11.2	55.2 $\pm$ 11.5	0.106

Table 2: ICC between HRR at baseline and 12-month follow-up at one and two minutes post-exercise.

	<b>ICC</b>	<b>95% Lower Confidence Limit</b>	<b>95% Upper Confidence Limit</b>	<b>P-value</b>
<b>HRR<sub>60</sub><sup>1</sup> and HRR<sub>60</sub><sup>2</sup></b>	0.864	0.797	0.909	<0.001
<b>HRR<sub>120</sub><sup>1</sup> and HRR<sub>120</sub><sup>2</sup></b>	0.789	0.684	0.859	<0.001
<b>ΔHRR<sub>60</sub><sup>1</sup> and ΔHRR<sub>60</sub><sup>2</sup></b>	0.728	0.594	0.818	<0.001
<b>ΔHRR<sub>120</sub><sup>1</sup> and ΔHRR<sub>120</sub><sup>2</sup></b>	0.711	0.568	0.806	<0.001

<sup>1</sup>Measurements collected in year 1 <sup>2</sup>Measurements collected in year 2



Table 3: Within-subject mean variability of absolute HRR data between baseline and 12-month follow-up.

<b>Variable</b>	<b>Mean</b> (± SD)	<b>CoV (%)</b>	<b>Lower</b> <b>LOA</b>	<b>Upper</b> <b>LOA</b>	<b>Mean bias</b>
<b>HRR<sub>60</sub></b> (b.min <sup>-1</sup> )	123.89 ± 12.61	10.2 (2.2 <sup>*</sup> )	-18.66	15.80	-1.43
<b>HRR<sub>120</sub></b> (b.min <sup>-1</sup> )	96.60 ± 12.39	12.8 (2.9 <sup>*</sup> )	-21.09	20.25	-0.42
<b>ΔHRR<sub>60</sub></b> (beats)	29.06 ± 9.49	32.7 (10.0 <sup>*</sup> )	-18.42	16.48	-0.82
<b>ΔHRR<sub>120</sub></b> (beats)	56.34 ± 11.15	19.8 (5.0 <sup>*</sup> )	-23.18	19.52	-1.83

<sup>\*</sup>CoV% based on log-transformed mean ± SD

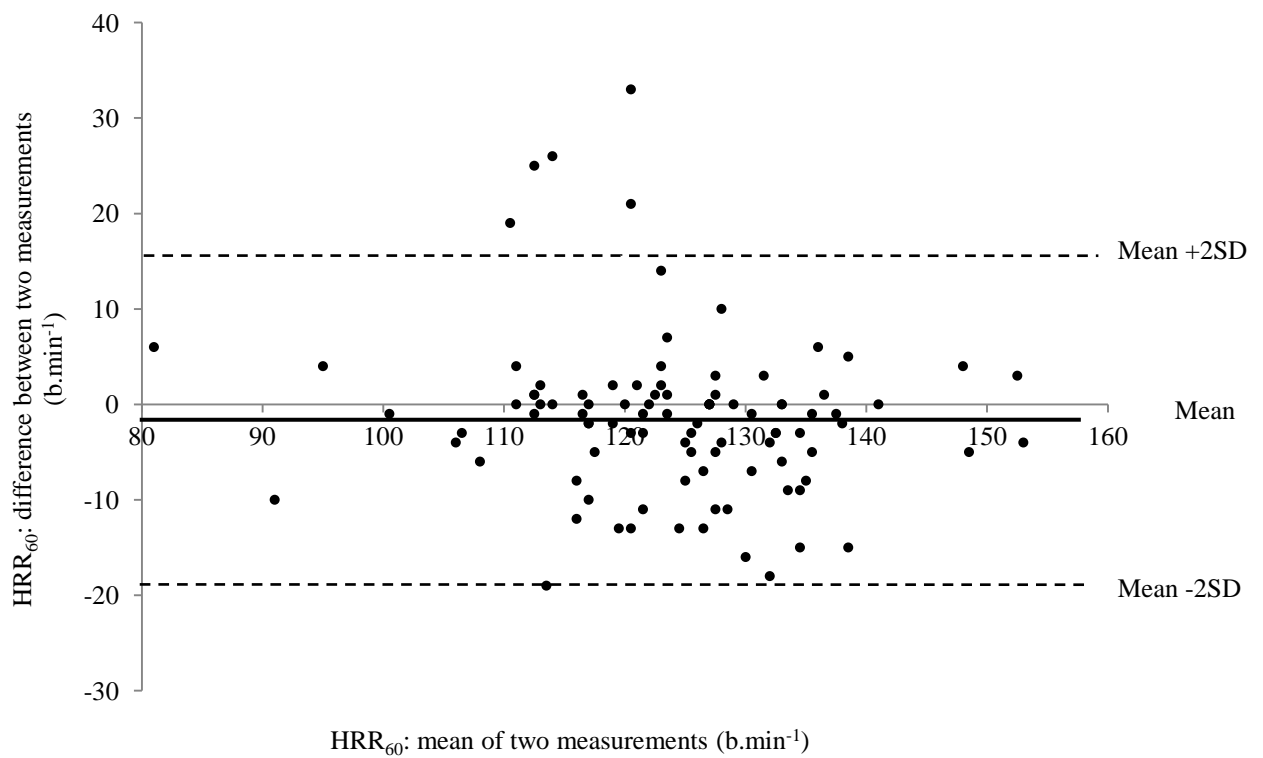


Figure 1: Bland-Altman plot displaying the 95% limits of agreement for absolute HRR<sub>60</sub>