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Heart-Rate Recovery after Graded Treadmill Exercise in Football, Volleyball, Athletics and Swimming Athletes: A Cross-Sectional Comparison at the University of Wasit, Iraq

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Abstract. Heart-rate recovery (HRR) after exercise is an inexpensive, non-invasive marker of cardiovascular and autonomic adjustment that is increasingly used to monitor athletes. Evidence on how HRR differs between athletes from different sports in Iraq is, however, lacking. This study compared heart-rate recovery after a standardised graded treadmill test among male university athletes from four sports. In a cross-sectional design, 40 male athletes aged 19–24 years (10 each from football, volleyball, athletics and swimming) affiliated with the University of Wasit completed a symptom-limited graded treadmill test followed by active recovery at 3 km/h on a level grade. Heart rate was recorded with a Polar H10 chest strap. HRR1 and HRR2 were defined as the fall in heart rate from peak to 60 and 120 seconds of recovery, and recovery time as the time needed to return to resting heart rate plus 10 beats/min. Groups were compared with one-way ANOVA, Tukey–Kramer post hoc tests and a planned contrast between endurance-based (athletics and swimming) and intermittent (football and volleyball) sports. HRR1 ranged from 33.2 ± 5.8 beats/min in football to 44.8 ± 4.9 beats/min in swimming, and recovery time from 512 ± 62 s in football to 372 ± 48 s in swimming. The four sports differed in HRR1 ($F(3, 36) = 10.48$, $\eta^2 = .47$), HRR2 ($F(3, 36) = 11.98$, $\eta^2 = .50$) and recovery time ($F(3, 36) = 13.67$, $\eta^2 = .53$), all $p < .001$. Endurance-based athletes recovered 9.6 beats/min more in the first minute (95% CI 6.0–13.1) and returned to near-resting heart rate 116 s sooner (95% CI 79–154) than intermittent-sport athletes. Athletes from endurance-based sports thus showed faster heart-rate recovery, a pattern consistent with greater aerobic training exposure. Because the design was cross-sectional and the samples small, HRR should be used for within-athlete monitoring rather than as a fixed standard for comparing sports.

Keywords: Heart-Rate Recovery, Autonomic Function, Graded Exercise Test, Athlete Monitoring, Endurance Training, Team Sports, Iraq.

1. Introduction

When exercise stops, heart rate does not return to its resting value at once. It falls rapidly during the first minute and then more slowly over the following minutes, as parasympathetic activity is restored and sympathetic activity and circulating catecholamines decline (Coote, 2010; Imai et al., 1994). The size of this fall, commonly expressed as heart-rate recovery (HRR) at one or two minutes after exercise, has attracted interest in both clinical and sport settings because it can be measured easily with inexpensive equipment.

In clinical populations, a small fall in heart rate during the first minute of recovery has been associated with higher mortality (Cole et al., 1999), and methodological work has examined how protocol and timing affect HRR values (Shetler et al., 2001). In athletes, faster recovery has been linked to higher training status and more rapid vagal reactivation (Daanen et al., 2012; Imai et al., 1994). HRR is therefore an attractive tool for coaches who wish to monitor how athletes respond to training. Its interpretation is not straightforward, however. HRR depends on exercise intensity and duration, the posture and activity during recovery, environmental conditions and the athlete's state on the day of testing, so a single value must be interpreted in context (Borresen & Lambert, 2008; Buchheit, 2014).

Sports differ considerably in their physiological demands. Distance running and swimming rely mainly on sustained aerobic metabolism, whereas football and volleyball combine aerobic work with repeated high-intensity actions (Mitchell et al., 2005). Differences in habitual training may therefore be reflected in recovery profiles. In Iraq, however, there are few published data on heart-rate responses of university athletes, and coaches have little local evidence to guide the use of HRR in monitoring.
The present study addresses this gap by comparing resting heart rate, HRR and recovery time after a common graded treadmill protocol among football, volleyball, athletics and swimming athletes at the University of Wasit.

1.1 Objectives of the Study

- To describe resting heart rate, peak heart rate and heart-rate recovery after a graded treadmill test among male university athletes.
- To compare HRR1, HRR2 and recovery time among athletes from football, volleyball, athletics and swimming.
- To examine the associations of peak heart rate and weekly training volume with recovery indices.

1.2 Hypotheses

H1: HRR1, HRR2 and recovery time differ significantly among the four sports.

H2: Athletes from endurance-based sports (athletics and swimming) show greater HRR and shorter recovery time than athletes from intermittent sports (football and volleyball).

H3: Recovery indices are significantly associated with peak heart rate and weekly training volume.

2. Conceptual and Physiological Framework

2.1 Autonomic Basis of Heart-Rate Recovery

The rapid fall in heart rate during the first 30–60 seconds of recovery is attributed mainly to the reactivation of cardiac vagal activity. Imai et al. (1994) showed that atropine markedly slowed this early phase and that it was faster in athletes than in untrained individuals or patients with heart failure. Later phases of recovery reflect a combination of continued vagal reactivation, withdrawal of sympathetic activity, clearance of metabolites and thermoregulatory adjustments (Coote, 2010; Peçanha et al., 2014). Pierpont et al. (2000) supported the use of early HRR as an index of parasympathetic activity, but HRR remains a composite signal and should not be treated as a direct measure of vagal tone.

2.2 Influence of Recovery Mode and Protocol

HRR is sensitive to the conditions under which it is measured. Active recovery, such as walking, keeps muscle pumps and metabolic demand elevated and generally produces slower heart-rate decline than passive recovery in a seated or supine position. Shetler et al. (2001) showed that the recovery protocol substantially affects HRR values and their prognostic thresholds. Values obtained under active recovery cannot therefore be compared directly with clinical thresholds derived from passive or different protocols. Bosquet et al. (2008) also showed that HRR measured over short intervals has only moderate day-to-day reliability, which limits the interpretation of single measurements.

2.3 Training Status and Sport Type

Endurance training increases resting vagal activity and stroke volume, and these adaptations are generally associated with lower resting heart rate and faster recovery after exercise (Borresen & Lambert, 2008; Daanen et al., 2012). The relationship is not uniform. Daanen et al. (2012) found that changes in HRR tracked changes in training status in many but not all studies, and Buchheit (2014) cautioned that HRR can also increase with acute fatigue in some circumstances. Classifying sports as endurance or intermittent is a simplification, since football and volleyball also impose substantial aerobic demands (Mitchell et al., 2005). In this study, the classification is used only to structure comparisons between the sport groups sampled.

3. Methodology

3.1 Research Design and Participants

A cross-sectional comparative design was used. Participants were 40 male athletes aged 19–24 years who trained in football, volleyball, athletics or swimming (n = 10 per sport) at sports academies affiliated with the University of Wasit, Al-Kut, Iraq. Participants were selected purposively. Testing took place between February and March 2026. Table 1 summarises the characteristics of the groups.

Table 1: Characteristics of Participants by Sport (n = 10 per group)

Variable	Football	Volleyball	Athletics	Swimming	*F*(3, 36)
Age (years)	21.3 ± 1.4	20.8 ± 1.2	21.5 ± 1.6	20.6 ± 1.3	0.92
Weekly training (h)	10.2 ± 1.8	8.5 ± 1.5	12.4 ± 2.1	14.0 ± 2.5	14.49*

Note: *Values are mean ± SD. *p < .001; swimming > football and volleyball, athletics > volleyball (Tukey–Kramer, p < .01). Age did not differ among groups (p = .44).*

Table 2: Graded Treadmill and Recovery Protocol

Phase	Timing	Speed / grade	Measurement
Rest	Before exercise	Seated, 5 min	Resting heart rate
Graded exercise	Up to 18 min	3.0–8.0 km/h; 5–16% grade (modified Bruce)	Heart rate, RPE, test duration
Termination	End of exercise	Symptom-limited	Peak heart rate
Active recovery	60 s	3 km/h; 0% grade	HRR1
Active recovery	120 s	3 km/h; 0% grade	HRR2
Active recovery	Until endpoint	3 km/h; 0% grade	Recovery time

Note: *RPE = rating of perceived exertion (Borg 6–20 scale).*

3.2 Instruments

Exercise tests were performed on a motorised treadmill. Heart rate was recorded continuously with a Polar H10 chest-strap monitor, and perceived exertion was rated with the Borg 6–20 scale. Standard anthropometric instruments were used to measure body dimensions.

3.3 Test Protocol

After five minutes of seated rest, athletes performed a modified Bruce-type graded treadmill test in which speed increased from 3.0 to 8.0 km/h and grade from 5% to 16% over a maximum of 18 minutes (Table 2). The test was terminated at volitional exhaustion. Recovery was active, consisting of walking at 3 km/h on a level grade until the recovery endpoint was reached.

3.4 Outcome Measures

Resting heart rate was the stable heart rate after five minutes of seated rest. Peak heart rate was the highest heart rate recorded during the test. HRR1 and HRR2 were calculated as peak heart rate minus heart rate at 60 and 120 seconds after the end of exercise, respectively. Recovery time was the time from the end of exercise until heart rate first reached the resting value plus 10 beats/min.

3.5 Statistical Analysis

Data are presented as means and standard deviations. Differences among the four sports were tested with one-way analysis of variance (ANOVA), with eta squared (η^2) as the effect size, followed by Tukey–Kramer post hoc comparisons with 95% simultaneous confidence intervals. Because the variances were similar across groups, standard ANOVA was used; Welch's ANOVA led to the same conclusions for all outcomes. Hypothesis H2 was tested with a planned contrast comparing the mean of athletics and swimming with the mean of football and volleyball, with Cohen's d calculated from the pooled within-group standard deviation (Cohen, 1988). Associations among variables were examined with Pearson's correlation coefficient, with 95% confidence intervals obtained by Fisher's z transformation. Statistical significance was set at $p < .05$. Analyses were performed with Python 3 (SciPy library).

3.6 Ethical Considerations

The study was approved by the Ethics Committee of the College of Physical Education and Sports Sciences, University of Wasit (approval no. ws sport.255-2025, dated 20 January 2025) before data collection. Participation was voluntary, all participants were aged 18 years or older, and informed consent was obtained from each participant after the purpose, procedures and risks of the test had been explained. Data were coded to protect confidentiality.

4. Results

4.1 Heart-Rate Responses of the Whole Sample

Across all 40 athletes, mean resting heart rate was 62.4 beats/min and peak heart rate 191.4 ± 5.8 beats/min. Heart rate fell to 152.7 ± 11.2 beats/min after one minute and to 128.4 ± 10.8 beats/min after two minutes of active recovery, giving mean HRR1 and HRR2 values of 38.7 and 63.0 beats/min, respectively. Table 3 presents the values by sport.

Table 3: Resting Heart Rate and Recovery Indices by Sport

Variable	Football	Volleyball	Athletics	Swimming	*F*(3, 36)	η²
Resting HR (beats/min)	66.4 ± 6.2	65.1 ± 5.8	58.8 ± 5.4	59.2 ± 5.9	4.56**	.28
HRR1 (beats/min)	33.2 ± 5.8	34.6 ± 6.1	42.1 ± 5.2	44.8 ± 4.9	10.48***	.47
HRR2 (beats/min)	55.4 ± 7.3	57.8 ± 7.8	68.2 ± 6.4	70.6 ± 5.8	11.98***	.50
Recovery time (s)	512 ± 62	488 ± 68	396 ± 54	372 ± 48	13.67***	.53

Note: *Values are mean ± SD; n = 10 per sport. p < .01; p < .001. Field data, 2026*

The four sports differed significantly on all four variables, with large effect sizes (η² = .28–.53). Athletics and swimming athletes had lower resting heart rates, larger falls in heart rate at one and two minutes, and shorter recovery times than football and volleyball athletes (Table 3; Figure 1). H1 was therefore supported.

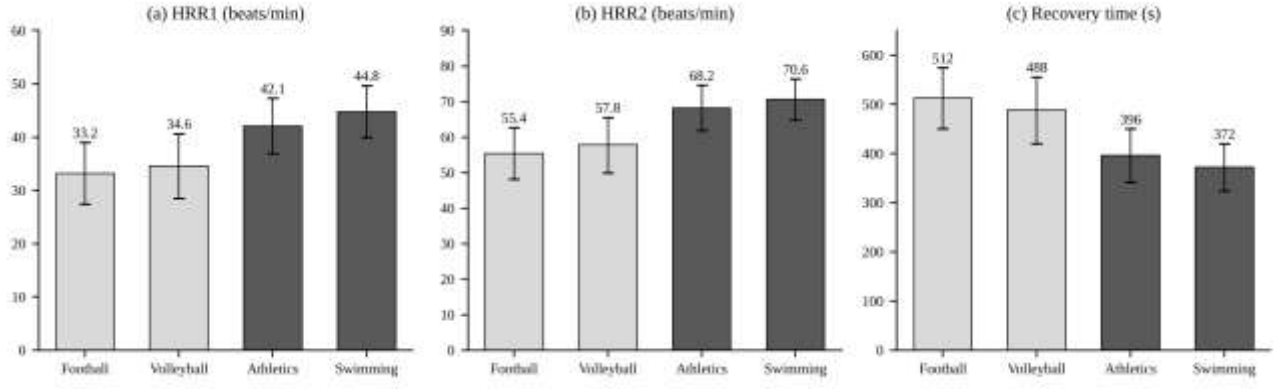


Figure 1: Mean (± SD) (a) HRR1, (b) HRR2 and (c) recovery time by sport. Dark bars represent endurance-based sports.

4.2 Pairwise Comparisons between Sports

Table 4: Tukey–Kramer Pairwise Comparisons of Recovery Indices

Comparison	HRR1 difference	95% CI	*p*	Recovery time difference (s)	95% CI
Volleyball − Football	+1.4	−5.3 to 8.1	.941	−24	−94 to 46
Athletics − Football	+8.9	2.3 to 15.6	.005	−116	−186 to −46
Swimming − Football	+11.6	5.0 to 18.3	< .001	−140	−210 to −70
Athletics − Volleyball	+7.5	0.9 to 14.2	.022	−92	−162 to −22
Swimming − Volleyball	+10.2	3.6 to 16.9	.001	−116	−186 to −46
Swimming − Athletics	+2.7	−4.0 to 9.4	.696	−24	−94 to 46

Note: *Differences in HRR1 are in beats/min. Recovery time p values: .796, < .001, < .001, .006, < .001 and .796, respectively. HRR2 followed the same pattern (endurance vs intermittent comparisons all p < .01; within-category comparisons p = .86).*

Post hoc comparisons showed a clear two-cluster structure (Table 4). Each endurance-based sport differed significantly from each intermittent sport in HRR1, HRR2 and recovery time, whereas there were no significant differences between football and volleyball or between athletics and swimming. For resting heart rate, athletics (p = .030) and swimming (p = .043) were lower than football, but neither differed significantly from volleyball.

4.3 Endurance-Based versus Intermittent Sports

Table 5: Planned Contrast between Endurance-Based (Athletics, Swimming) and Intermittent (Football, Volleyball) Sports

Variable	Mean difference	95% CI	*t*(36)	*p*	*d*
Resting HR (beats/min)	−6.75	−10.49 to −3.01	−3.66	< .001	−1.16
HRR1 (beats/min)	+9.55	6.01 to 13.09	5.47	< .001	1.73
HRR2 (beats/min)	+12.80	8.39 to 17.21	5.89	< .001	1.86
Recovery time (s)	−116.00	−153.52 to −78.48	−6.27	< .001	−1.98

Note: *Mean difference = endurance-based minus intermittent.*

The planned contrast confirmed H2. On average, endurance-based athletes recovered 9.6 beats/min more in the first minute and 12.8 beats/min more in the second, reached the recovery endpoint about two minutes sooner, and had resting heart rates almost 7 beats/min lower than intermittent-sport athletes. All effect sizes were large ($|d| = 1.16–1.98$).

4.4 Correlations among Variables

Table 6: Correlations between Heart-Rate Variables and Training Volume (n = 40)

Variables	*r*	95% CI	*p*
Peak HR and HRR1	−0.682	−0.819 to −0.470	< .001
Peak HR and HRR2	−0.714	−0.839 to −0.518	< .001
Weekly training volume and HRR1	0.584	0.333 to 0.758	< .001
HRR1 and recovery time	−0.792	−0.885 to −0.638	< .001

Note: *Correlations are calculated across the pooled sample of four sports.*

Higher peak heart rate was associated with smaller HRR1 and HRR2, and greater weekly training volume was associated with larger HRR1 (Table 6). Athletes with larger HRR1 also returned to near-resting heart rate more quickly ($r = −0.792$). H3 was therefore supported. Because the correlations were calculated across four sport groups that differ in training volume and recovery, they partly reflect differences between groups rather than relationships within them.

5. Discussion

5.1 Differences in Recovery between Sports

The main finding of this study is that athletes from athletics and swimming recovered faster after graded treadmill exercise than athletes from football and volleyball. The difference was consistent across HRR1, HRR2 and recovery time, and the post hoc analysis revealed two distinct clusters rather than a gradual ranking of four sports. This pattern agrees with evidence that endurance training enhances vagal reactivation after exercise (Daanen et al., 2012; Imai et al., 1994) and with the lower resting heart rate observed in the endurance-based groups, which is a recognised marker of aerobic training adaptation (Borresen & Lambert, 2008).

The groups also differed in training volume: swimmers and track athletes trained more hours per week than footballers and volleyball players, and training volume was positively associated with HRR1. The sport differences may therefore reflect training volume as much as the type of training. Because training volume and sport were confounded, and aerobic capacity was not measured directly, the study cannot determine whether sport type, training volume, prior selection into sports or other individual characteristics explain the differences. The results describe differences between the groups sampled rather than effects of practising a particular sport.

5.2 Peak Heart Rate and Recovery

Higher peak heart rate was associated with smaller HRR. This finding requires careful interpretation. Because HRR is calculated by subtracting recovery heart rate from peak heart rate, the two variables are mathematically linked, and their correlation may be influenced by this coupling as well as by physiology. The negative direction observed here is also consistent with the group structure: athletes with lower aerobic training may reach higher peak values relative to their resting level and recover more slowly. The relationship should be examined within sports and with individual data before physiological conclusions are drawn.

5.3 Physiological Interpretation and Its Limits

The early fall in heart rate is largely vagally mediated (Imai et al., 1994; Pierpont et al., 2000), but recovery under active walking also reflects continued muscle work, metabolic by-products and body temperature (Coote, 2010; Peçanha et al., 2014). The present measures should therefore be described as non-invasive indicators of recovery rather than direct measures of autonomic function. Similarly, the clinical threshold of 12 beats/min proposed by Cole et al. (1999) was derived from older patients tested with a different protocol and does not apply to young athletes recovering actively.

5.4 Practical Implications

HRR can be measured with an ordinary chest-strap monitor and offers coaches a practical way to follow athletes' responses to training. The large differences between sports suggest that comparisons should be made within the same sport and, preferably, within the same athlete over time under standardised conditions (Buchheit, 2014). Because single measurements have limited reliability (Bosquet et al., 2008), HRR should be interpreted alongside training load, perceived exertion, sleep and health status, and should not be used on its own for medical clearance, diagnosing overtraining or selecting talent.

5.5 Limitations

The study was cross-sectional and included only 40 male athletes from one university, with ten participants in each sport. Participants were selected purposively, which limits generalisation. Aerobic capacity, body composition and pre-test conditions such as sleep and prior training were not controlled. Recovery was active, which limits comparison with studies using passive recovery. Finally, correlations were calculated on the pooled sample and may partly reflect group differences.

6. Recommendations

Based on the findings of this study, the following recommendations are made:

Standardised Monitoring: Coaches and sports scientists should use a fixed exercise and recovery protocol, record the time of each measurement and check devices regularly when using HRR to monitor athletes.

Individual Reference Values: HRR should be compared within the same athlete over time and within the same sport, rather than against values from other sports or clinical thresholds.

Integrated Interpretation: HRR should be interpreted together with training load, perceived exertion, sleep and symptoms, and not used alone for medical or selection decisions.

Future Research: Future studies should include female athletes and larger samples, measure aerobic capacity directly, follow athletes longitudinally across training phases and analyse relationships within sports.

7. Conclusion

This study compared heart-rate recovery after a graded treadmill test among male university athletes from four sports in Wasit, Iraq. Athletes from athletics and swimming had lower resting heart rates, faster falls in heart rate during the first two minutes of recovery and shorter recovery times than athletes from football and volleyball, with large differences between the two groups of sports and no significant differences within them. Recovery was also associated with weekly training volume. These findings are consistent with greater aerobic training exposure in endurance-based sports, but the cross-sectional design and small samples do not allow causal conclusions or the establishment of normative values. HRR is best used as a practical, low-cost tool for monitoring individual athletes over time under standardised conditions.

Declarations

Funding: This research received no external funding.
Conflict of Interest: The author declares no conflict of interest.
Data Availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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