Heart rate recovery in elite Spanish male athletes

A. B. PEINADO [1], P. J. BENITO [1], M. BARRIOPEDRO [2], I. LORENZO [3], N. MAFFULLI [4,5], F. J. CALDERÓN [1]

[1]Departamento de Salud y Rendimiento Humano, Facultad de Ciencias de la Actividad Física y del Deporte (INEF), Universidad Politécnica de Madrid, Madrid, Spain
[2]Departamento de Ciencias Sociales de la Actividad Física, del Deporte y del Ocio Facultad de Ciencias de la Actividad Física y del Deporte (INEF), Universidad Politécnica de Madrid, Madrid, Spain
[3]Universidad Camilo José Cela, Madrid, Spain
[4]Department of Musculoskeletal Surgery, University of Salerno School of Medicine and Surgery, Baronissi, Salerno, Italy
[5]Queen Mary University of London Barts and The London School of Medicine and Dentistry, Institute of Health Sciences Education, Centre for Sports and Exercise Medicine, Mile End Hospital, London, UK

***Aim.* During postexercise recovery, heart rate (HR) initially falls rapidly, followed by a period of slower decrease, until resting values are reached. The aim of the present work was to examine the differences in the recovery heart rate (RHR) between athletes engaged in static and dynamic sports.**

***Methods.* The study subjects were 294 federated sportsmen competing at the national and international level in sports classified using the criteria of Mitchell *et al.* as either prevalently static (N.=89) or prevalently dynamic (N.=205). Within the dynamic group, the subjects who practised the most dynamic sports were assigned to further subgroups: triathlon (N.=20), long distance running (N.=58), cycling (N.=28) and swimming (N.=12). All athletes were subjected to a maximum exertion stress test and their HR recorded at 1, 2, 3 and 4 min ($RHR_{1,2,3,4}$) into the HR recovery period. The following indices of recovery (IR) were then calculated: $IR_1 = (HR_{peak} - RHR_{1,2,3,4}) / (HR_{max} - HR_{rest}) * 100$, $IR_2 = (HR_{peak} - RHR_{1,2,3,4})/(HR_{max} / HR_{peak})$, and $IR_3 = HR_{peak} - RHR_{1,2,3,4}$. The differences in the RHR and IR for the static and dynamic groups were examined using two way ANOVA.**

***Results.* The RHR at minutes 2 (138.7±15.2 *vs.* 134.8±14.4 beats·min^{-1}) and 3 (128.5±15.2 *vs.* 123.3±14.4 beats·min^{-1}) were significantly higher for the static group (Group S) than the dynamic group (Group D), respectively. Significant differences were seen between Group D and S with respect to IR_1 at minutes 1 (26.4±8.7 *vs.* 24.8±8.4%), 2 (43.8±8.1 *vs.* 41.5±7.8%), 3 (52.1±8.3 *vs.* 49.1±8%) and 4 (56.8±8.6 *vs.* 55.4±7.4%) of recovery. For IR_2, significant differences were seen between the same groups at minutes 2 (59.7±12.5 *vs.* 55.9±10.8 beats·min^{-1}) and 3 (71.0±13.5 *vs.* 66.1±11.4 beats·min^{-1}) of recovery. Finally, for IR_3, the only significant difference between Group D and S was recorded at minute 3 of recovery (72.2±12.5 *vs.* 66.2±11.5 beats·min^{-1}).**

***Conclusion.* This work provides information on RHR of a large population of elite Spanish athletes, and shows marked differences in the way that HR recovers in dynamic and static sports.**

Key words: Sports - Heart rate - Recovery.

Corresponding author: N. Maffulli, MD, MS, PhD, Queen Mary University of London, Barts and The London School of Medicine and Dentistry, Centre for Sports and Exercise Medicine, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK.

The heart rate (HR) response during exercise and the relevant physiological mechanisms involved have been widely studied.[1, 2] In the past century heart rate recovery has been studied (Pugh 1967), but only recently it has been specifically targeted.[3-12] This is surprising, since recovery heart rate (RHR) is commonly measured as part of the monitoring of the training process,[13] and in the assessment of cardiovascular condition.[14] Recovery heart rate might have prognostic value in monitoring heart disease [15-17] and other health problems involving abnormalities of the autonomic nervous system, such as diabetes.[18] A fall in HR of less than 12 beats·min^{-1} in the first minute of recovery is considered abnormal.[16] However, poor test-retest reproducibility would make it problematic to use RHR in the clinical interpretation of stress tests.[19]

Classically, the decrease in HR after exercise is exponential, with an initial rapid reduction in HR followed by a gentler decrease.[20] The slow phase of recovery may last several minutes, depending on the duration and intensity of the exercise undertaken.[21, 22] Studies on the effect of training on RHR indicate that recovery is significantly faster following a period of endurance training,[11, 23, 24] a well described effect of endurance training.[25, 26] Also, the greater the dynamic component of a sport, the younger the age, and the smaller the body mass index (BMI), the better the RHR.[27]

To date, no data have been available on heart rate recovery in elite Spanish athletes following a maximum exercise test. The aim of the present work was to obtain the differences in RHR in elite Spanish athletes, classified as either static or dynamic athletes according to Mitchell et al.[28] classification. Since both the volume and intensity of training for dynamic sports are considerably greater, and therefore likely to lead to greater cardiac adaptation, it was hypothesised that the HR of athletes whose training involved a large dynamic component would recover more swiftly that those whose training involved a large static component. The secondary aim was to determine whether, within the dynamic sports group, athletes in different specialities (long distance running, cycling, triathlon and swimming) exhibited different RHR values.

Materials and methods

Participants

The present work involved 294 elite male athletes (mean age 22±7 years; mean body weight 74.3±16.1 kg; mean height 179.3±15.7 cm) who competed at national and/or international level. The athletes were divided into two groups according to the classification criteria of Mitchell *et al.*[28]: Group S (for "more static"; N.=89), representing sports with a relatively low dynamic component and a low-moderate static component, *e.g.*, Olympic marksmen, archers, fencers, golfers, and judo and karate fighters, and Group D (for "more dynamic"; N.=205), representing sports with high dynamic component and a low-high static component, *e.g.*, long distance runners, triathletes, basketball players, cyclists, swimmers and kayakers. Sixty one members of Group D – those whose sports had the greatest dynamic and smallest static components, *i.e.*, those specialising in triathlon (N.=20), long distance running (N.=58) (low static/high dynamic components), cycling (N.=28) (high static/high dynamic components) and swimming (N.=12) (moderate static/high dynamic components), were further assigned to subgroups representing these specialities. All subjects were informed about the modalities, aims and risks of the study, both verbally and in writing. Signed consent to participate was sought from all those taking part, according to the Helsinki Declaration regarding research involving human beings. The study was approved by the Ethics Committee of the Universidad Politécnica de Madrid. All experiments were performed at the Centro Nacional de Investigación Deportiva (CENID; the National Centre for Sports Research), a centre under the auspices of the Consejo Superior de Deportes (CSD) de España (the Spanish Sports Council).

Protocol

All participants were subjected to an incremental exercise test until exhaustion, involving the use of a Jaeger ER800 cycloergometer (for use with the cyclists) or a DANSPRINT kayakergometer (for use with the kayakers), or a Laufer-Ergotest L_6 treadmill (for use with all other athletes). Rest and exercise heart rate was measured using a 12-lead electrocardiograph (ECG) (Marquette Electronics, Inc., Milwaukee, WI, USA), with all the electrodes positioned to capture data in the frontal and horizontal planes. Postexhaustion recovery was passive in a sitting position to obtain good ECG readings, measuring the HR over the first 4 min of the recovery period. The HR was therefore measured at rest (HR_{rest}), at its exercise peak (HR_{peak}), and at minutes 1-4 of recovery (RHR_1, RHR_2, RHR_3, and RHR_4). HR_{peak} refers to the averaged five highest HR reached during the incremental test. The maximum theoretical HR was determined as HR_{max} =220 – age. The following RHR indices were also determined: 1) IR_1 - the index of recovery proposed by Calderon *et al.*[8, 29] (Equation 1); 2) IR_2 - the index of recovery proposed by Lamiel-Luengo [29] (Equation 2); and 3) IR_3 - the index of recovery [27], calculated as the difference between the HR_{peak} and HR at a corresponding recovery time (Equation 3).

$$IR_1 = (HR_{peak} - RHR_{1,2,3,4}) / (HR_{max} - HR_{rest}) * 100 \text{ (Equation 1)}$$

$$IR_2 = (HR_{peak} - RHR_{1,2,3,4}) / (HR_{max} / HR_{peak}) \text{ (Equation 2)}$$

$$IR_3 = HR_{peak} - RHR_{1,2,3,4} \text{ (Equation 3)}$$

Statistical analysis

Differences in age, body weight, height, training variables (years in training, etc.), HR_{rest} and HR_{peak} between Group S and Group D were examined using the Student t test for independent samples. The RHR and IR values were examined by two way ANOVA; the independent variables were GroupD/S and the time of data collection during the recovery period (minute 1, 2, 3 or 4). The values for HR_{rest} and HR_{peak} for each Group D subgroup (triathlon, long distance running, cycling and swimming) were examined by one way ANOVA. Two way ANOVA was then repeated with sporting speciality (Group D subgroup) and time of data collection during the recovery period (minute 1, 2 3 or 4) as the independent variables. *Post hoc* multiple comparisons were performed using the Bonferroni test. Significance was set at $P<0.05$. All calculations were performed using SPSS v.18.0 software (SPSS Inc., Chicago, IL, USA).

Results

Table I shows the anthropometric characteristics of Group D and Group S athletes. The athletes in group D were significantly taller ($t_{131}=4.5$; $P<0.001$) and younger ($t_{291}=3.9$; $P<0.001$) than the athletes in group S. No correction for age was necessary since the age range of the subjects would not have led to differences in heart rate recovery. No significant differences were seen between the groups in terms of body weight ($t_{291}=0.8$; $P>0.05$). The D subjects had trained for fewer years than the S subjects ($t_{120}=8$; $P<0.001$) and trained fewer hours per day ($t_{102}=2.2$; $P<0.05$).

Table II shows the values for HR_{rest}, HR_{peak}, and

TABLE I.—*Anthropometric characteristics of the Group D and Group S subjects (mean±SD; range in brackets).*

	Group D	Group S
Age	20.8±6 (11-47)	25.1±8.2 (12-48)*
Body weight (kg)	73.5±14.1 (37.2-120)	75.1±20.1 (31-189.3)
Height (cm)	181.3±11.7 (150.7-216.8)	173.5±21.7 (1.8-195.6)*
Years in training	6.6±3.2 (1-16)	10.7±4.8 (2-21)*
Training volume (km/week)	104.2±28.9 (45-160)	
Hours of training (h/week)	3±1 (1-6)	3.4±1.4 (1-8)*

*Significantly different with respect to Group D (P<0.05).

TABLE II.—*Recovery heart rate in Group D and S (mean±SD).*

	HR_{rest} (beats·min⁻¹)	HR_{peak} (beats·min⁻¹)	RHR_1 (beats·min⁻¹)	RHR_2 (beats·min⁻¹)	RHR_3 (beats·min⁻¹)	RHR_4 (beats·min⁻¹)
Group D	57.2±9.4	195.6±9.9	158.9±15.4	134.8±14.4	123.3±14.4	117.0±14.6
Percentile 5	42	180	134	112	101	93.3
25	52	189	149.25	125	114	107
50	56	195	159	134	123	117
75	64	202	169	144	132	126
95	74.7	214	184.75	161	147.8	142
Group S	60.5±11.6*	194.7±10.4	161.3±14.5	138.7±15.2*	128.5±15.2*	120.0±14.2
Percentile 5	42	178	136.55	115.1	103	98.5
25	51.5	187.5	151	126.75	118	110.5
50	60.5	194	161	138	130.5	119
75	70	203	173	150	138	129
95	79.1	211	186.7	166.8	155.8	146.4

HR_{rest}: resting heart rate; HR_{peak}: peak heart rate during incremental exercise test; RHR_1: recovery heart rate after 1 min; RHR_2: recovery heart rate after 2 min; RHR_3: recovery heart rate after 3 min; RHR_4: recovery heart rate after 4 min. *Significantly different with respect to Group D (P<0.05).

TABLE III.—*Recovery indices at the minute 1, 2, 3 and 4 recovery times (mean±SD).*

	Group D			Group S		
	IR_1 (%)	IR_2 (beats·min⁻¹)	IR_3 (beats·min⁻¹)	IR_1 (%)	IR_2 (beats·min⁻¹)	IR_3 (beats·min⁻¹)
Minute 1	26.4±8.7	36.1±12.5	36.7±12.4	24.8±8.4*	33.3±11.3	33.4±11.4
Minute 2	43.8±8.1	59.7±12.5	60.7±11.9	41.5±7.8*	55.9±10.8*	56.0±11.2
Minute 3	52.1±8.3	71.0±13.5	72.2±12.5	49.1±8.0*	66.1±11.4*	66.2±11.5*
Minute 4	56.8±8.6	77.2±13.0	78.6±12.1	55.4±7.4*	74.6±10.5	74.7±10.7

IR_1: Calderón index; IR_2: Lamiel-Luengo index; IR_3: classic index of recovery. *Significantly different with respect to Group D (P<0.05).

RHR_{1-4} for both groups, and the distribution of these values by quartiles. No significant difference was seen between Group D and S in terms of HR_{peak} ($t_{292}=0.7$; $P>0.05$). However, the S subjects had a higher HR_{rest} ($t_{136}=2.4$; $P<0.05$), and during recovery their HR was higher ($F_{1,292}=4.3$; $P<0.05$), with significant differences at minute 2 ($F_{1,292}=4.130$; $P<0.05$) and 3 ($F_{1,292}=7.932$; $P<0.05$).

Table III shows the ANOVA results for the indices of recovery recorded (IR_1, IR_2 and IR_3). All were higher in Group D than in Group S ($F_{1,292}=5.3$; $P<0.05$ for IR_1; $F_{1,292}=6.3$; $P<0.05$ for IR_2; $F_{1,292}=11$; $P<0.001$ for IR_3). Differences were seen between Groups D and S with respect to IR_1 at minutes 1 ($F_{1,292}=6.093$; $P<0.05$), 2 ($F_{1,292}=6.962$; $P<0.05$), 3 ($F_{1,292}=8.417$; $P<0.05$) and 4 ($F_{1,292}=6.694$; $P<0.05$) of recovery. For IR_2, differences were seen between the same groups at minutes 2 ($F_{1,294}=6.474$; $P<0.05$) and 3 ($F_{1,294}=9.319$; $P<0.05$) of recovery. Finally, for IR_3, the only significant difference between Group D and S was recorded at minute 3 of recovery ($F_{1,287}=7.344$; $P<0.05$).

HR_{peak} differed between the members of the Group D subgroups ($F_{3,110}=7.8$; $P<0.001$). The swimmers had the highest HR_{peak} at 206.2±11 beats·min⁻¹, a value significantly higher than that recorded for the remaining three subgroups (long distance runners 194.8±9.2 beats·min⁻¹; cyclists 198.6±7 beats·min⁻¹; triathletes 191.5±8.4 beats·min⁻¹). Differences were also seen between these subgroups in terms of HR_{rest} ($F_{3,116}=3.7$; $P<0.05$); the swimmers had a significantly higher HR_{rest} than the long distance runners (62.4±11.9 beats·min⁻¹ compared to 53.7±8.1 beats·min⁻¹) and triathletes (53.7±9.6 beats·min⁻¹), although no difference was seen with the cyclists (58±10.7 beats·min⁻¹).

The RHR also differed between these subgroups ($F_{3,114}=7.4$; $P<0.001$). The interaction recovery minute x sport speciality (subgroup) exerted a significant influence on heart rate recovery ($F_{9,342}=2.7$; $P<0.01$) (Figure 1). At 1 and 2 min into the recovery period, the triathletes showed significantly lower RHR values than the other subgroup specialists; in addition, the values for the cyclists and long distance runners were significantly lower than those of the swimmers. At minutes 3 and 4, the RHR of the triathletes was lower than those recorded for all the other specialist subgroups ($P<0.05$). Finally, in minute 4, the swimmers had a significantly higher RHR than the long distance runners ($P<0.05$) (Figure 1).

Discussion

This report provides unique descriptive data on the HR of elite Spanish athletes of different specialities following maximum exertion. An important finding of the present work is the difference in the way in which HR recovers in both the Group D and Group S athletes, confirming the expectation that the type of training undertaken would induce differences in the RHR. In fact, differences in heart rate recovery were also seen between the Group D speciality subgroups.

After the first minute of recovery, the RHR values recorded were 37±12 beats·min⁻¹ for Group D and 33±11 beats·min⁻¹ for Group S. These results are similar to those reported by Antelmi *et al.*,[30] who indicated HR to decline in the first minute of recovery by 30±12 beats·min⁻¹. At 2 min into the recovery period, the present results were also higher than those reported by the latter authors (61±12 beats·min⁻¹ in Group D and 56±11 beats·min⁻¹ in group S compared to 52±13 beats·min⁻¹ for the healthy subjects of the latter study). The subjects examined by Antelmi et al., however, were not elite athletes. This suggests that heart rate recovery is improved in athletes.

With respect to the indices of recovery calculated, IR_1 would appear to more precisely reflect the proc-

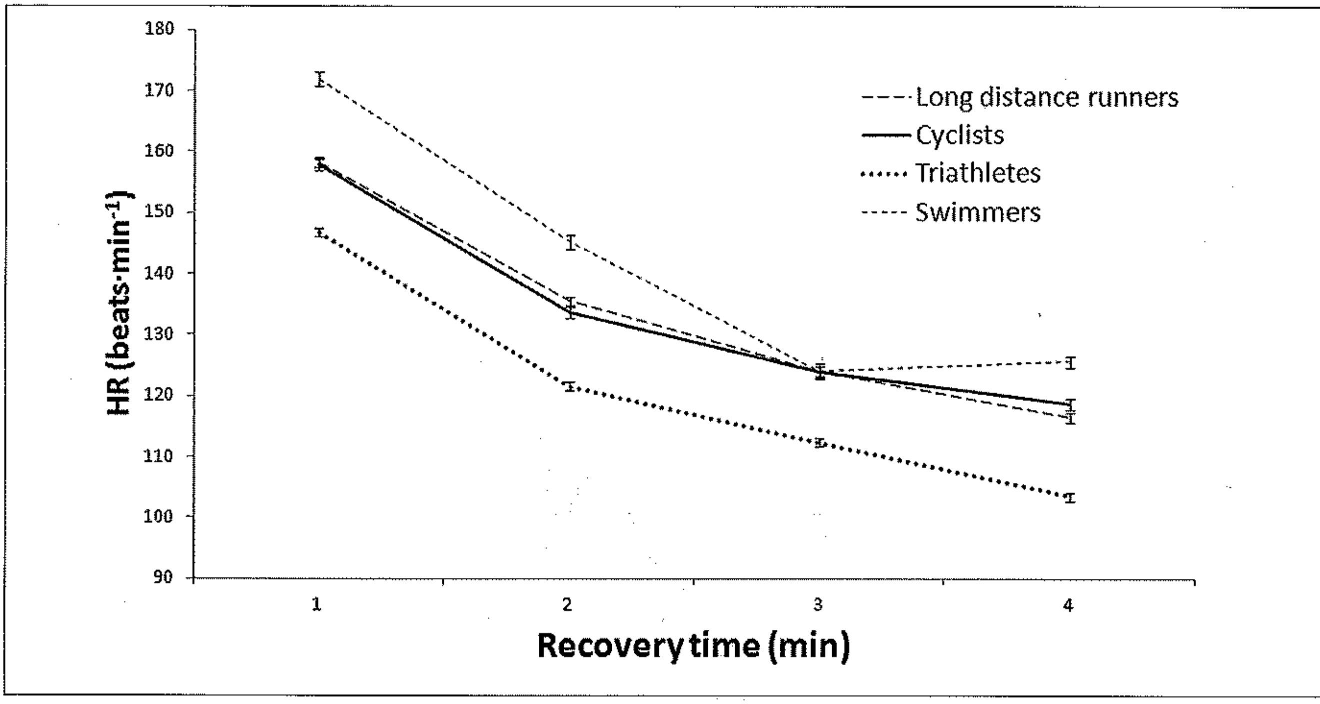

Figure 1.—Recovery of the heart rate in athletes of the Group D specialist subgroups. The values indicated are means±SD.

ess of heart rate recovery since it takes into account HR reserve and not just the difference between the peak and baseline values.[31] The latter authors defined a slow recovery in HR as a fall of <22 beats·min^{-1} after a 2 min recovery period. In the present work, the mean reduction over the first 2 min of the recovery period was 44±11 beats·min^{-1}. This notably greater reduction probably results from the elite status of our athletes, unlike those in the work of the latter authors. It should also be noted that even the RHR values in the 75th and 95th percentiles represented a reduction greater than 12 beats·min^{-1} after the first minute of recovery; no recovery rates indicative of a pathological condition were therefore seen.[19]

During recovery, the excitatory activity of the central nervous system on the cardiovascular system involves both central (nervous pacemaker signals at different levels of the neuroaxis) and peripheral signals (from baro-, chemo-, lung- and mechanoreceptors). The fact that, during the first minute of recovery, RHR was not different in Group D and Group S athletes may indicate that the mechanisms intervening in the fall in HR (cerebral cortex-central command) [32] function independently of the training undertaken. In addition, this lack of difference between the two groups at this time suggests that the activation of the parasympathetic nervous system, which exerts a major influence to reduce HR in the first post-exercise minutes (rapid phase),[12, 15, 20, 32] is not affected by training. The type of training undertaken by Group D subjects imposes greater demands on the cardiovascular system, and therefore a better sympathetic/parasympathetic balance might be expected; this would determine a more rapid recovery of the HR in the first minutes following exercise.[11, 23, 24] In contrast, during the second and third minute of the recovery period, the RHR was different in the Group D and Group S. Now, the mechanisms (cerebral cortex-central command) intervening in the fall in HR and the activation of the parasympathetic nervous system may have determined a more rapid recovery in the Group D. The phase of more progressive descent in HR could be affected by type of training.

The differences observed in recovery between the four groups of Group D (triathletes, long distance runners, cyclists, and swimmers) athletes must have a complex physiological explanation as there should be no differences in the cardiovascular regulation mechanisms that control recovery in each subgroup.

Thus, the fact that the swimmers have a higher HR during recovery (Figure 1) might be related to the conditions under which they engage in training. The position of the body influences the way in which systolic volume is adjusted at different intensities of exercise [33], so that at maximum intensity the final diastolic volume is greater when lying down than when standing. Thus, swimmers might be used to working at high intensity with a lower HR. Since the stress test for the swimmers was not performed using an ergometer specific for their sport, their recovery times might be different from what experienced while swimming. In the future, further research with sport-specific ergometers is required.

Some studies have reported differences in recovery with respect to age,[34] although in the present work age differences would probably be too small to have any effect.

We are aware of the limitations of the study. For example, our study did not address the possible differences in the frequencies spectrum between different sports. The possible differences could explain better the results of this study, because the heart rate variability is an indirect method of assessing the vegetative activity on the heart vegetative.

In conclusion, this study showed that in a large population of elite Spanish athletes dynamic training determines the recovery of HR over the first 4 min of the post-exhaustion recovery period. The data produced could serve as reference values against which those of individuals of different cardiorespiratory condition (including sedentary people) could be compared.

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Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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