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Brief Report

Resting Heart Rate Measurement in Elite Athletes during COVID-19 Lockdown: The Impact of Decreased Physical Activity

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Abstract: The purpose was to observe the effects of a four-week lockdown on the resting heart rate (RHR) and well-being perception of elite swimmers. Twenty elite swimmers performed RHR measurements upon waking in supine and standing positions. Baseline values and those measured after four weeks of lockdown were compared. Swimmers completed a questionnaire on their training volume and state of well-being. During the lockdown, swimmers reported a weekly mean physical activity of 10.4 ± 3.6 h (an estimated reduction of 254% compared to their usual training volume). After four weeks of lockdown, RHR in the supine position increased by more than two beats per minute (58.8 ± 8.2 vs. 56.5 ± 7.4 bpm, $p < 0.05$). In the standing position, RHR increased by almost 15 beats per minute (103.3 ± 13.2 vs. 88.4 ± 9.4 bpm, $p < 0.0001$). Fifty percent of these athletes expressed a decrease in well-being. These results underline that the lockdown circumstances induced a large reduction in parasympathetic activity in elite athletes, which was associated with a decrease in training volume. This increase in RHR may reflect that a highatly strenuous environment and maintaining a high level of physical activity in this population could be favorable to preserve physical and psychological health.

Keywords: physiology; training load; well-being; swimmers; heart

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1. Introduction

With the escalating COVID-19 pandemic resulting in confirmed cases exceeding 3 million [1], a rigorous global containment concerning more than 2 billion people was established [1,2] and at the time of writing had been in effect for more than five weeks in most countries. This lockdown induced a large reduction in daily physical activity in all the layers of the population, including of course elite athletes, which could have potential negative effects on health [3]. In addition, considering the postponement of most international events such as the Olympic Games and world or continental championships, most elite athletes find themselves without short-term performance objectives, while they were psychologically and physically focused on the Tokyo Olympics for several months. This new situation could be perceived as very stressful and frustrating, and may lead to the adoption of lifestyle habits that could be detrimental to mental and physical health.

In order to rapidly resume training and competitions, elite athletes are currently trying to maintain their physical, physiological, and psychological condition despite the lockdown. Maintaining physical activity levels will also prevent the decline of metabolic and immune functions [4]. A few non-invasive measurements, carried out distantly, can provide objective information on their level of fitness. Among these monitoring tools, heart rate (HR) is a relevant one: resting heart rate (RHR) and HR variations have already proved their ability to monitor performance and fatigue levels in elite sport [5], especially in elite swimmers [6]. Monitoring athletes through HR can improve our understanding of the effects on health caused by the lockdown. During this period, HR monitoring seems to be the most appropriated method to observe changes in the status of the autonomic nervous system and cardiovascular system [7]. An increase in resting HR could be related with a decrease in vagal tone [8]. In addition, measures of well-being are essential for appreciating the acute and chronic impact of the lockdown with high sensitivity and consistency [9]. This is important as low indices of well-being increase the risk of injury in this population [10]. Psychological measures are a common and practical tool for monitoring training and condition [11].

After the description of potential physiological changes in elite athletes due to lockdown [12] and the challenges they have encountered [13], the purpose of this report is to evaluate the impact of four weeks of lockdown on the RHR of elite swimmers.

2. Materials and Methods

2.1. Participants

This study included two elite training groups from the French Swimming Federation. Twenty swimmers participated in this study (11 females; 9 males), with a mean age of 17.5 ± 2.4 years old for females and 19.9 ± 2.1 years old for males. All were specialist short or middle distance (100 to 400 m) swimmers and their personal best event (according to the international swimming federation table; i.e., FINA points) was between 83% and 97% of the world record points. Prior to participation, athletes were informed of the purpose of the study and the data collection involved. Written consent was obtained. For athletes below the age of 18 years, written consent was provided by their parent/guardian. All investigations conformed to the code of ethics of the World Medical Association (Declaration of Helsinki). A declaration of the study was made and approved by the Commission Nationale de l'Informatique et des Libertés (CNIL) with the following registration number: 2218805.

2.2. Experimental Overview

The pre-lockdown recordings were taken between September 2019 and March 2020, while the second set of recordings were taken during the 4th week of the lockdown in France (7–13 April of 2020) during the COVID-19 pandemic. Swimmers performed three weekly HR (on Monday, Wednesday and Friday) recordings at both time points. The first period (before lockdown) was characterized by "classic" training, with a volume of training in the water greater than 18 h per week for all participants, and 2 to 4 dryland training sessions. The second period (during lockdown), was limited to dryland training, including both strength and cardiovascular sessions.

2.3. Heart Rate Recordings

RHR was collected in both supine and standing positions with the use of a smartphone application (Elite HRV, © Elite HRV®, Asheville, United States of America, as previously described [6]. It consisted of an 11-min. test (6 min. supine followed by 5 min. in a standing position after waking up and without fluid or feed intake). Swimmers usually do these tests three times a week throughout the training season. HR measurements were recorded with a heart rate belt (Polar H10, Polar Electro Oy, Kempele, Finland) and transmitted by Bluetooth using the smartphone application (Elite HRV). The last 4 min. of HR recordings for the supine and standing positions were analyzed. All HR recordings were visually inspected for stationarity and corrected for artefact and ectopic beats via Kubios' in-built piecewise cubic spline interpolation [6]. Data were always inspected by the same researcher (principal investigator: RP).

2.4. Self-Reported Questionnaire

A self-reported training volume and state of well-being questionnaire was conducted on the Monday, after the 4th week of the lockdown. To facilitate the data collection in the cohort of swimmers, we asked them to complete an online questionnaire. This technique is commonly used by the swimmers during the training season. We collected two items: training volume (in hours), and changes of well-being state (decrease, equal, or increase from pre-lockdown period).

2.5. Statistical Analysis

Once the experimental sessions were completed, swimmers were ranked according to the decrease in training load. Those who experienced a decrease of more than twice their baseline training volume (>200%) were assigned to the high decrease group (HIGH) while those who experienced a decrease of less than twice their baseline training volume (>200%) were assigned to the low decrease group (LOW). Swimmers were also sorted according to sex (male vs. female), self-assessment of well-being (decrease vs. stability or increase), and swimming event (sprint vs. middle-distance) in order to test the influence of these variables on the lockdown-induced effect on supine or standing heart rate. Standard statistical methods were used for the calculation of means and standard deviations. Normal Gaussian distribution of the data was verified by the Shapiro–Wilk test, and homogeneity of variance by a modified Levene test. A paired t-test for dependant samples was used to test the null hypothesis that dependant variables (pre- to post-changes) were not altered by the four-week lockdown. An unpaired Welch's t-test (unequal variances) was performed to test the null hypothesis that independent variables were not altered by the four-week lockdown, whatever the sex, the swimming event, the percentage decrease in training load, or the self-assessment of well-being (differences in the changes between groups). Null hypothesis was rejected at $p < 0.05$. The magnitude of difference between independent samples was assessed by Cohen's d in order to measure the strength of relationships between the variables. The magnitude of difference was considered either trivial (<0.20), small (0.20 to 0.49), moderate (0.50 to 0.79), or large (0.80 and more). Calculations were made with Statistica (StatSoft, Tulsa, United States of America).

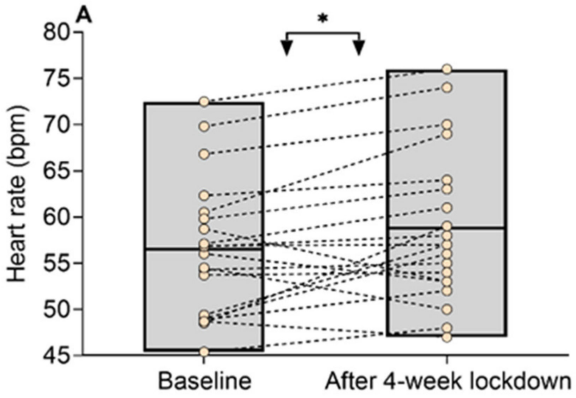
3. Results

3.1. Overall Results

Average training volume decreased from 24.1 $\pm$ 3.2 to 10.4 $\pm$ 3.6 h·week^{-1} ($p < 0.0001$), corresponding to an overall 254 $\pm$ 73% decrease after the 4th week of lockdown. Thirty percent of our sample of elite swimmers decreased their training volume by 4 to 8 h./week^{-1}, 35% by 8 to 12 h./week^{-1}, and 35% by more than 12 h·week^{-1}. This important decrease in training volume clearly impacted the self-assessment of well-being, since 50% of the swimmers reported a decrease, while only 20% reported an improvement. Regarding RHR, we observed a significant increase in the supine position (56.5 $\pm$ 7.4 vs. 58.8 $\pm$ 8.2 bpm, $p < 0.05$), and also a significant increase in the standing position (88.4 $\pm$ 9.4 vs. 103.3 $\pm$ 13.2 bpm, $p < 0.0001$) (Figure 1).

3.2. Specific Results

We identified several variables among available data that could potentially affect RHR response to the lockdown (i.e., percentage decrease in training volume, sex, swimming event, and well-being). Training volumes of each of the categories of these variables are presented in Table 1.



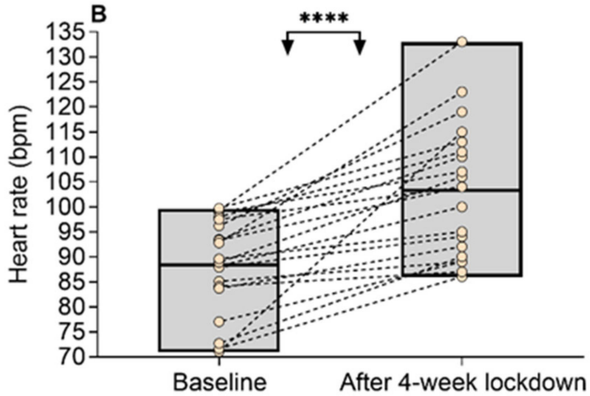


Figure 1. Resting heart rate (RHR) during baseline and after four-week lockdown in supine (**A**) and standing positions (**B**) in 20 elite swimmers. * $p < 0.05$, **** $p < 0.001$.

Table 1. Effect of lockdown on training volume (hours).

		Pre- to Post-Changes				Differences in the Changes		
	n	Pre- (Hours)	Post- (Hours)	Difference (%)	*p*-Value	Difference (%)	*p*-Value	Cohen's d
Decrease in training volume								
Low	8	25.6 (3.2)	14.0 (2.1)	185 (24)	<0.0001	115 (18)	<0.0001	2.67
High	12	23.0 (2.9)	8.0 (2.1)	300 (56)	<0.0001			
Sex								
Females	11	22.2 (2.6)	8.5 (2.7)	278 (70)	<0.0001	−53 (31)	0.10	0.76
Males	9	26.3 (2.3)	12.7 (3.5)	225 (70)	<0.0001			
Swimming event								
Sprint	9	25.0 (3.1)	10.4 (3.7)	263 (74)	<0.0001	−16 (34)	0.39	0.23
Middle distance	11	23.3 (3.0)	10.4 (4.0)	247 (65)	<0.0001			
Self-reported well-being								
Decrease	10	22.9 (3.4)	8.8 (3.3)	283 (73)	<0.0001	−58 (31)	0.08	0.84
Stability/increase	10	25.2 (2.7)	12.0 (2.7)	225 (65)	<0.0001			

As expected, we observed an important difference between the categories of training volume reductions (low vs. high, $p < 0.001$). We did not observe any significant differences between other variables. However, we observed a tendency toward a more important decrease in females vs. males ($p < 0.10$, ES = 0.76), as well as in swimmers who reported a decrease in well-being in comparison with those who maintained or improved it ($p < 0.08$, ES = 0.84). We did not find any effect of swimming event ($p > 0.05$, ES = 0.23).

RHR measured in supine position is presented for each variable in Table 2. Swimmers who reported a decrease in well-being demonstrated a significant increase in supine RHR ($p = 0.02$), while it remained unchanged in those who maintained or improved their well-being during the lockdown ($p = 0.52$). We also observed a significant increase in supine RHR for middle-distance swimmers ($p = 0.02$) while it remained unclear for sprinters ($p = 0.39$). We did not find any interaction between the categories of other variables ($p > 0.05$).

Table 2. Effect of lockdown on resting heart rate (RHR) in supine and standing positions.

		n	Pre- (bpm)	Post- (bpm)	Difference (bpm)	*p*-Value	Difference (bpm)	*p*-Value	Cohen's d
Supine position	**Decrease in training volume**								
	Low	8	54.9 (8.4)	58.4 (9.7)	3.4 (4.5)	0.09	−1.9 (2.0)	0.36	−0.46
	High	12	57.5 (6.8)	59.0 (7.5)	1.3 (3.7)	0.15			
	Sex								
	Females	11	60.6 (6.9)	62.8 (8.4)	2.2 (4.2)	0.12	0.3 (1.9)	0.87	0.07
	Males	9	51.4 (4.2)	53.9 (4.8)	2.5 (4.3)	0.12			
	Swimming event								
	Sprint	9	55.6 (4.3)	57.0 (6.4)	1.4 (4.6)	0.39	−1.7 (1.9)	0.39	0.40
	Middle distance	11	57.2 (8.3)	60.3 (8.3)	3.1 (3.9)	0.02			
	Self-reported well-being								
	Decrease	10	58.2 (7.3)	62.0 (7.5)	3.8 (4.1)	0.02	−3.0 (1.8)	0.10	−0.77
	Stability/increase	10	54.8 (7.4)	55.6 (8.0)	0.8 (3.7)	0.52			
Standing position	**Decrease in training volume**								
	Low	8	91.2 (5.6)	100.7 (8.2)	9.5 (5.1)	0.001	9.0 (3.9)	0.03	0.98
	High	12	86.6 (11.0)	105.1 (15.8)	18.5 (11.9)	<0.001			
	Sex								
	Females	11	90.4 (9.7)	107.3 (13.4)	16.8 (12.2)	<0.001	−4.3 (4.6)	0.36	−0.42
	Males	9	86.0 (9.0)	98.5 (11.8)	12.5 (8.3)	0.001			
	Swimming event								
	Sprint	9	88.1 (9.6)	103.9 (16.9)	15.7 (10.0)	0.001	1.5 (4.8)	0.76	−0.14
	Middle distance	11	88.7 (9.6)	102.9 (10.6)	14.2 (11.9)	<0.001			
	Self-reported well-being								
	Decrease	10	89.5 (9.6)	107.4 (14.4)	17.9 (13.4)	<0.001	−5.9 (4.7)	0.23	−0.58
	Stability/increase	10	87.4 (9.5)	99.3 (11.1)	11.9 (6.1)	0.001			

RHR measured in a standing position is presented for each variable in Table 2. We observed a significant difference between the categories of decrease in training volume. The group with the more important decrease (>200%) in training volume demonstrated a more important increase in standing RHR ($p = 0.03$) (Figure 2). We did not find any other association or interaction between the categories of other variables.

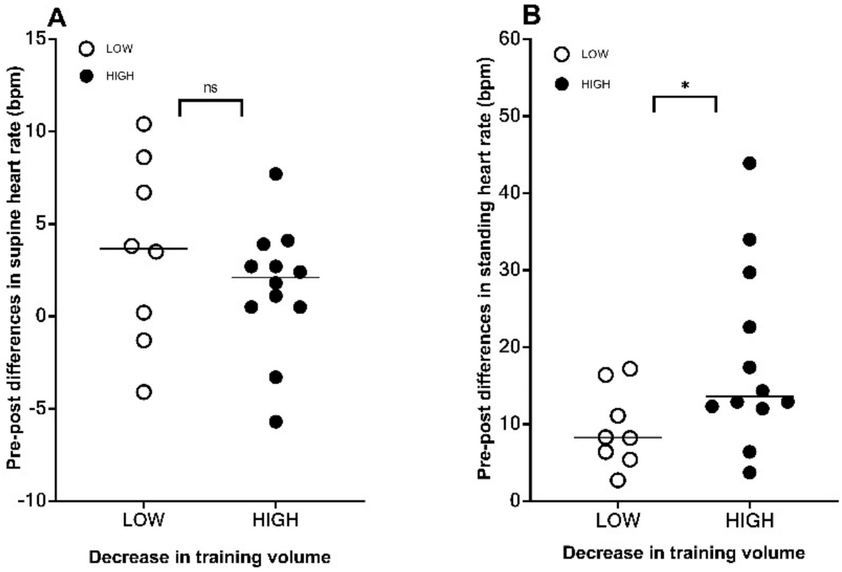


Figure 2. Changes in resting heart rate (RHR) in supine (**A**) and standing positions (**B**) depending on low (<200% from training volume baseline) vs. high (>200% from training volume baseline) decrease in training volume in 20 elite swimmers. * $p < 0.05$.

4. Discussion

This study is the first to report changes in RHR in athletes during four weeks of imposed lockdown. A notable increase in HR, especially in a standing position, was observed, which was associated with a decrease in training volume and well-being.

4.1. RHR and Body Position

A variation in HR may be explained by the structural changes in the sinus node [14], but the interpretation of the data could differ according to the position (supine or standing) [15]. In our study, we observed slightly different results depending on body position, with a large increase in standing HR for all participants after four weeks of lockdown, while only a small increase was observed in the supine RHR. As suggested by some researchers [8,16,17], the HR is more subject to autonomic balance changes in the standing position. As Portier et al. found [8], our data on standing position RHR suggests parasympathetic activity reduction after four weeks of lockdown, but it was not clear for the supine position. In the supine position, in trained athletes with low heart rates, it is possible to observe parasympathetic saturation [18]. During an orthostatic test, vagal and sympathetic regulation act reciprocally [19,20]. The change of body position causes a decrease in venous return which induces a decrease in cardiac stroke volume and arterial blood pressure, which in turns leads to parasympathetic withdrawal (and so increase in HR) through baroreflex-mediated autonomic regulation [21]. This is why the standing test seems to be more appropriate for measuring cardiac autonomic function in athletes [18]. In 2004, Mourot et al. showed that non-overtrained athletes had greater reactivity to the postural change than overtrained athletes [22]. Uusitalo et al. (1999) also reported that decrease in vagal activity in standing position was correlated with decrease in maximal aerobic power in athletes, whereas no correlation was observed in the supine position [23]. In a previous study in an open-water world champion, it was reported that the only HR/HRV parameter which changed over the days of the week was the standing HR [6]. In another study in elite swimmers by Hellard et al. [24], muscular injuries, all type pathologies and upper respiratory tract infection were associated with a drop in parasympathetic drive in orthostatic position. Taken together, these results suggest that in this study, increased standing RHR could lead to an increased risk of injury and illness, and decreased performance.

4.2. RHR and Training Volume

Our results show that swimmers who had a greater decrease in their training volume had a greater increase in their standing RHR and they are similar to those reported by Portier et al. [8], who showed that elite athletes had a higher RHR in the standing position after a rest period compared to an intensive training period [8]. A prolonged period of training cessation could lead to detraining, characterized by alterations in the cardiorespiratory system and metabolic patterns [25]. It was also shown that elite athletes increased HR in exercise to counterbalance the decreased stroke volume during that period of training cessation [25]. It is well established that the greater the volume of daily physical activity, the greater the peak oxygen uptake and the lower the HR [26]. Aerobic training seems to be the most favorable for reducing HR in elite swimmers [26]. With higher HR observed in these swimmers, it is highly likely that they lost aerobic capacity during lockdown, mainly due to a decrease in training volume and physical activity. Huovinen et al. [27] revealed that an increase in standing HR during a mentally stressful period in military service was well correlated with a decrease in testosterone-to-cortisol ratio. As described by Atlaoui et al., it is also possible that a reduction in training volume induced an increase in catecholamines [28], which is related to an increas in HR and reflects augmented sympathetic activity [29].

4.3. RHR and Well-Being

Evaluating mental well-being is also relevant in these circumstances as 50% of the athletes expressed a decrease in well-being. These results are higher than those recently reported in the general population, highlighting that 32% of people have a lower mental well-being compared to before the COVID-19 epidemic [30]. We observed that swimmers who reported a decrease in well-being demonstrated a tendency toward an increase in supine RHR, while no change was observed in those who maintained or improved their well-being during the lockdown. Therefore, it seems essential to maintain regular physical activity to reduce mental health risk and to avoid the increased risk of physical injury [31]. A systematic review already suggested that detraining periods, similarly to periods of injury, are associated with depression syndromes in elite athletes [32]. A recent study also showed that people who stay physically inactive during lockdown reported poorer psychological, social, and environmental quality of life domain scores than active people [33]. In these lockdown circumstances, it can be assumed that not only is the context anxiety-provoking, but the physical deconditioning as well. A more thorough multifaceted approach using workload indicators (internal and external) and psychological follow-up may be important to further understand the links between such variables.

4.4. Monitoring and Prevention

In the context of the lockdown, the use of smartphone applications to provide data on HR could allow physicians to help patients and coaches to help athletes with the interpretation of their results [34]. Considering the evidence of the negative effects on physical health with elevated RHR, it seems essential to measure it regularly during lockdown. Hallman et al. [35] also showed that each hour of standing per day is associated with a 0.7 bpm reduction in normal RHR. It is largely possible that these effects have been amplified during the lockdown, in relation to the reduction in the number of hours spent in standing position. Though athletes maintained a mean physical activity of 10.4 ± 3.6 h per week, a significant increase in HR was observed. This HR increase may be a potential indicator of detraining or a negative adaptation to training but in this case, additional measures of training tolerance may be required to identify in more detail the physiological changes during this period [36]. In elite athletes under lockdown, monitoring is essential to regulate the dose of physical activity in order to compensate for negative effects caused by this unprecedented period.

4.5. Limits

This study was conducted under very specific conditions and necessarily suffers some limitations. The swimmers were living at home and the investigators could not control some parameters as precisely as usual. First of all, it was not possible to control the swimmers' lifestyle. Consequently, the potential influence of sleep, diet, hydration, body mass, and menstrual cycles on RHR could not be assessed. It also would be interesting to determine if the reduction in training volume affected blood pressure. Moreover, training load was estimated from data transmitted by the swimmers. Considering the difficulty in assessing training intensity, they just reported training volume, which is only a proxy of training load.

5. Conclusions

After four weeks of lockdown, we measured a significant increase in RHR in high-level swimmers, which was more pronounced in the standing position. These results were associated with a decreased training volume during this period and a depreciation in well-being for 50% of participants. The effects of such reductions may have negative repercussions on cardiovascular, mental, and global health. It is essential that this population is capable of quickly returning to a sufficient, more sport-specific, and diversified training load in order to maintain their standard physical fitness and to achieve optimal performance in the coming months. Such variations or declines should be monitored in the general population as well.

Author Contributions: R.P. conceived the idea and collected the data. R.P. encouraged A.A., J.-F.T., A.S., and L.B. to investigate the findings of this work. R.P. took the lead on the manuscript and was helped by A.S. to supervise the project. A.A. helped with reference collection. R.P., J.-F.T., and A.S. discussed the research direction. L.B. wrote the methods and results sections. All authors accepted the final version of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Prior to participation, athletes were informed of the purpose of the study and the data collection involved. Written consent was obtained. For athletes below the age of 18 years, written consent was provided by their parent/guardian.

Data Availability Statement: Data is available by request.

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Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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