



Daily Heart Rate Variability during an 18-Day Staging Camp in Paralympic Medallist Swimmers

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ABSTRACT

Edmonds RC, Leicht AS, McKean M, Burkett B. Daily Heart Rate Variability during an 18-Day Staging Camp in Paralympic Medallist Swimmers. **JEPonline** 2014;17(4):84-92. The purpose of this study was to quantify the daily fluctuations in heart rate variability (HRV) during taper for elite Paralympic medallist swimmers with various impairments. Ten-min supine recordings of 6 male elite Paralympic medallist swimmers were collected upon awakening each morning for the 18 days of taper leading into the London 2012 Paralympic games. Weekly training volume reduced from an average of 43 km·wk⁻¹ to 23.5 km·wk⁻¹ (45%) during the taper period. Daily HRV analysis during the taper period showed significant changes in HRV that followed a trend across all amputee athletes. Daily RMSSD was significantly reduced on day two (40.6% decrease from average) of the taper before peaking on day 13 (13.7% increase from average). An athlete with a neuromuscular impairment did not follow the same trend. There was a significant difference in HRV across Paralympic swimmers with varying impairments. The daily monitoring of training post international travel highlighted important highs and lows that may be used as indicators in readiness to perform.

Key Words: Autonomic Nervous System, Taper, Swimming, Disability, Athlete

INTRODUCTION

Modifying an athlete's training load in the final days before major competition (i.e., taper) has long been used by coaches to enhance performance (7,12). The result of the taper is the optimization of a person's performance from being recovered and at maximum physical and psychological preparedness (2). It is well understood that during periods of intense training, vagal indices of heart rate variability (HRV) diminish acutely, then bounce back beyond their pre-training level during successive periods of lighter training or appropriate recovery (1,7,9). This apparent rebound in HRV has been shown to be associated with enhanced performance in recreationally trained and well trained athletes (1,7). Similarly, lower HRV levels during the lead up to competition have also been correlated with superior performances (9,11). It has been suggested this reduced background of parasympathetic modulation (9,11) may potentially reflect an increased readiness to perform or athlete 'freshness' (15).

Previous research investigating HRV and performance in able-bodied swimmers has shown that increased HRV during periods of reduced training was correlated with increased performance (7). Garet and colleagues (7) identified a correlation ($R^2 = 0.57$, $P < 0.0001$) between higher cardiac autonomic activity and performance in experienced swimmers during a period of reduced training. This relationship has been reported in able-bodied athletes (7), but has not yet been examined in a Paralympic sporting environment. While it has been reported that Paralympic swimmers follow similar periodized training programs as Olympic swimmers do (6), there is little information about how Paralympic swimmers with varying disabilities respond within their taper (6).

The purpose of this study was to: (a) examine HRV in elite Paralympic swimmers during the taper period prior to a major international competition; and (b) identified any potential differences in cardiac autonomic activity between elite Paralympic swimmers with contrasting impairments. Results of this study may provide guidance to further individualize training workloads of elite Paralympians according to their impairment.

METHODS

Subjects

All swimmers (age: 22 ± 2.8 ; height: 1.86 ± 0.09 ; weight: 76.8 ± 8.4) had been competing at the international level for an average of 7 yrs, having been members of at least two international teams in the lead up to the 2012 Paralympic games. Ethics approval from the local institution and written informed consent from all subjects were obtained prior to participation. The International Paralympic Committee (IPC) swimming classification code and impairment category was applied to each subject as following: (a) neuromuscular; (b) minor amputee (i.e., below the knee/elbow amputation); and (c) major amputee (i.e., above the knee/elbow amputation) (Table 1).

Procedures

During the staging camp, resting HRV of 6 male Paralympic swimmers was recorded each morning for the last 18 days immediately leading into the 2012 Paralympic games. Short-term (10 min) heart rate (HR) recordings were obtained via a Suunto Memory belt (Suunto memory belt, Suunto Oy, Finland) immediately after waking each morning of the taper period. Two days before the staging camp all athletes travelled from Brisbane to London, which involved a 23-hr international flight and then a 3-hr bus trip from London to Cardiff. The team arrived in Cardiff around midday the day before the camp commenced, with all athletes completing a light recovery swim that afternoon.

Table 1. Subject Characteristics.

	Age (yrs)	Height (m)	Weight (kg)	Athlete (Classification) ^a	Disability	Swimming Background (yrs) ^b
Athlete 1	24	1.88	85	S10	Neuromuscular	10
Athlete 2	21	1.88	84	S8	Minor Amputee	5
Athlete 3	26	1.70	62	SM10	Minor Amputee	10
Athlete 4	19	1.91	77	S9	Major Amputee	3
Athlete 5	19	1.95	74	S9	Major Amputee	5
Athlete 6	23	1.83	79	S9	Major Amputee	8

^aAthletes classified according to the IPC Classification Code, ^bIndicates years competing as part of the national Paralympic swim team.

All HR data were analyzed using Kubios HRV software (v2.1, University of Kuopio, Finland), as previously described (4). To ensure that steady-state at rest was achieved, HRV was calculated during the last 5 min of supine rest. HRV analysis focused on RMSSD since it indicates vagal activity (17) and has been shown to be a valid and reliable indicator of cardiac autonomic control in athletes (4,14). All artifact and ectopic beats (<5%) identified after visual inspection of all HR recordings were replaced using Kubios's intrinsic cubic spline interpolation (16). Daily kilometers (km) obtained from consultation with the Paralympic swim team head coach were also recorded to document training volume during the staging camp. Upon further discussion with the head coach, it was determined that aerobic based training sessions were generally 6 to 8 km of lower intensity sets with shorter rest periods while training sessions between 4 to 6 km were considered quality sessions that incorporated a mixture of speed and aerobic based swim sets. In addition, training sessions between 2 and 4 km were considered speed sessions and comprised higher intensity sets with longer rest periods during training.

Statistical Analysis

Data normality was assessed using a Kolmogorov-Smirnov test of normality with a Lilliefors correction. Data from subjects were grouped according to impairment with analyses between groups completed using a Friedman's test and Conover *post hoc* comparisons. All data were examined using daily values and an alpha level of $P < 0.05$ with data expressed as mean (95% Confidence Interval). A straightforward crossover trial to assess raw and percentage effect statistics was also used to determine absolute and relative differences between athletes and between impairment groups (i.e., neuromuscular, minor amputee, and major amputee). Relationships between HRV and daily km swam were identified by Spearman's rank rho (ρ) correlation coefficients.

RESULTS

During the staging camp, the subjects' average weekly training volume decreased by 45% from the previous weekly training average of $43 \text{ km} \cdot \text{wk}^{-1}$ to $23.5 \text{ km} \cdot \text{wk}^{-1}$. Weak relationships ($P > 0.05$) were identified between HRV and daily km completed during the taper period. There was no significant difference in mean HR within each impairment group throughout the taper period. During the taper, RMSSD (ms) was at its absolute lowest on day 2 for subjects with amputee impairment, and at its

highest on day 13 (Figure 1). However, RMSSD for the neuromuscular athlete did not follow the same trend (Figure 1). It was the lowest on day 7 and highest on day 13.

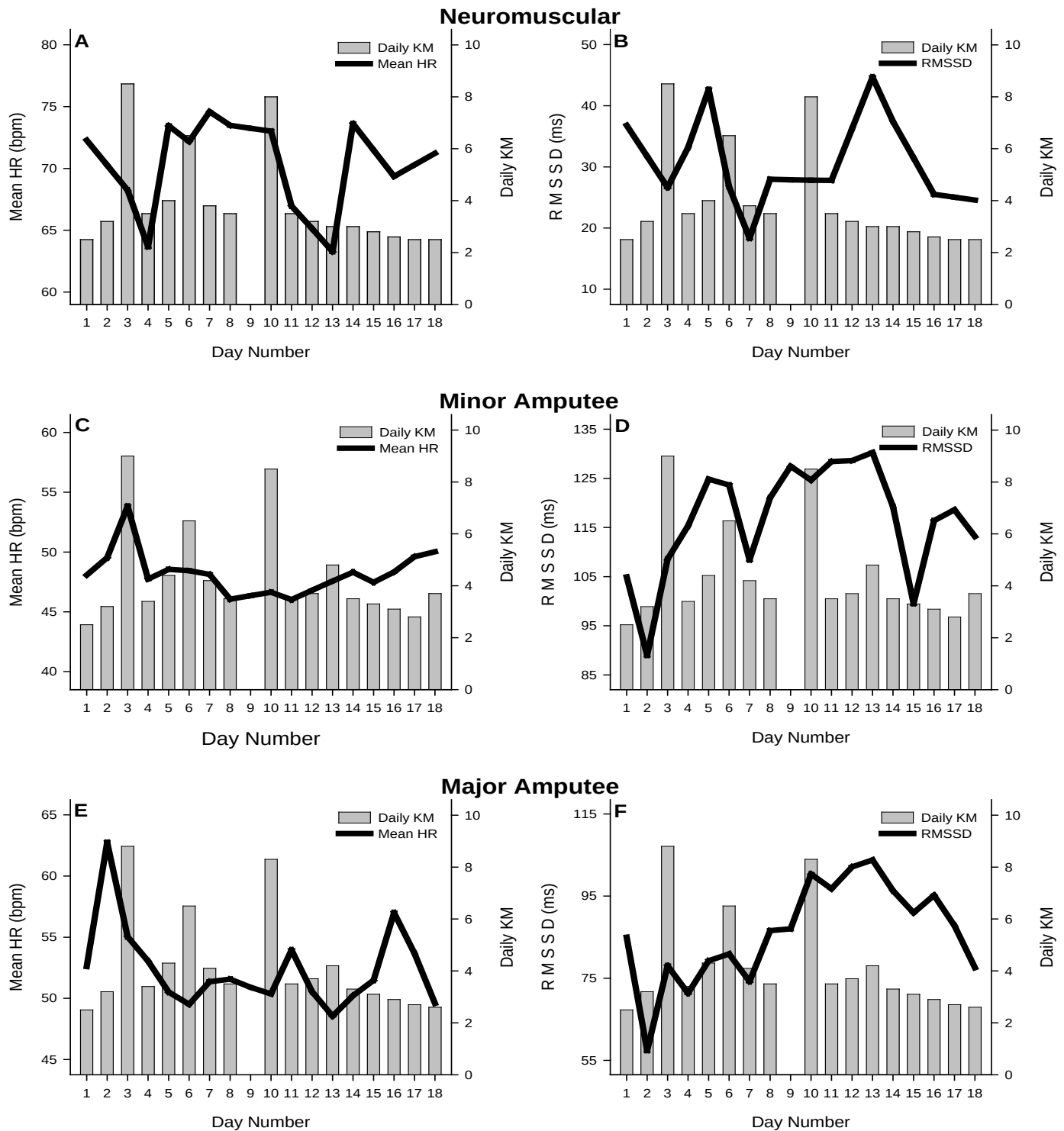


Figure 1. Daily HRV Over the 18-Day Taper for Each Impairment Group Graphed Against Daily Kilometers Completed. A, C, E. Mean HR for each impairment group; B, D, F. RMSSD for each impairment group; Values are expressed as the daily group average for HRV and daily KM. HR = heart rate; RMSSD = square root of the mean squared difference of successive RR intervals

Mean HR was significantly higher while RMSSD (ms) was significantly lower for the subject with a neuromuscular disability compared to the subjects with a minor or major amputation (Figure 2 and Table 2). In a similar way, RMSSD (ms) was significantly lower while mean HR was significantly higher for the subjects with a major amputation compared to the subjects with a minor amputation (Figure 2 and Table 2).

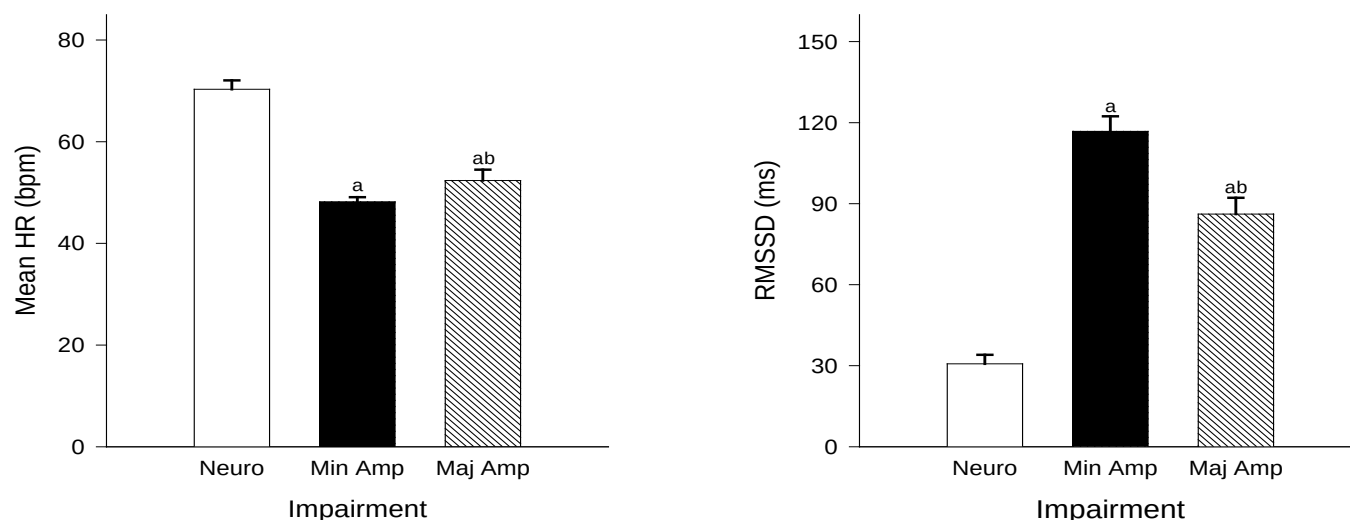


Figure 2. Average HRV during the Taper for Each Impairment Group. Values are mean (+95% confidence interval). HR = heart rate; RMSSD = square root of the mean squared difference of successive RR intervals. ^aSignificantly different to neuromuscular athlete ($P < 0.05$). ^bSignificantly different to minor amputee ($P < 0.05$).

Table 2. Differences between Impairment Groups, Expressed in Absolute and Relative (%) Terms for all HRV Measures averaged over the 18-day Taper.

	Neuromuscular vs. Minor Amputee		Neuromuscular vs. Major Amputee		Minor Amputee vs. Major Amputee	
	Absolute	Relative (%)	Absolute	Relative (%)	Absolute	Relative (%)
Mean HR (beats·min ⁻¹)	22.1 * (20.1 - 24.1)	45.8 * (41.3 - 50.5)	17.9 * (15.3 - 20.6)	34.4 * (28.7 - 40.2)	-4.2 * (-5.8 - -2.6)	-7.9 * (-10.6 - -5.1)
RMSSD (ms)	-86.1 * (-92.6 - -79.6)	-135.4 * (-147.4 - -123.4)	-55.5 * (-61.9 - -49.1)	-104.5 * (-116.9 - -91.9)	30.6 * (25.9 - 35.3)	30.9 * (25.6 - 36.3)

Values are expressed as mean (95% CI). HR, heart rate; RMSSD, square root of the mean squared difference of successive RR intervals * $p < 0.05$ between athletes.

DISCUSSION

Morning resting HRV responses were recorded in 6 male Paralympic swimmers during an 18-day pre-competition staging camp that led up to the London 2012 Paralympic Games. All swimmers performed exceptionally well and received medals in their events. This study appears to be the first documentation of daily HRV in Paralympian swimmers during a taper in preparation for a Paralympic competition. During the taper period, a high range of variation among the elite Paralympic swimmers was evident. The success of the swimmers at the games as determined by personal best times

indicated that this fluctuating cardiac modulation may be normal and appropriate to reach maximum performance times.

Daily analysis of HRV provided more detail than previous once-a-week monitoring, which may also be better suited during a pre-competition training phase. While few studies have shown that increased HRV during periods of reduced training is associated with an increase in performance (1,7), these results and conclusions thereof are based on weekly or twice weekly HRV recordings. More recently, day to day variations in HRV have been suggested as a means to assess potential overtraining (14). Findings from the current study suggest day to day variations may also be beneficial in gauging an athlete's readiness to perform (15).

During the course of the 18 day taper, HRV appeared to follow a trend in amputee athletes. There was a significant depression of RMSSD (ms) (average 40.6% depression) 2 days into the taper with RMSSD (ms) rebounding back higher than previous values 13 days (average 13.7% rebound) into the taper. While a number of studies have shown an acute decrease in HRV following periods of intense training (9,13), this finding (i.e., reduction in HRV) could potentially be related to the long haul (>20 hrs) international flight in the 3 days prior to the 18-day taper period. While there is limited knowledge as to how long-duration travel effects HRV, reduced cardiac vagal activity has been reported among people that had recently experienced significant stress (3), a common condition experienced during a long travel period (18). It is interesting that the reduction in HRV was not an immediate response to the travel, but rather potentially a cumulative effect of the travel along with the recommencement of training in the lead up to the Paralympic games. Yet, it is noteworthy that there were no apparent relationships evident between HRV for each impairment group and daily kilometers completed during the taper period.

Although both amputee groups had an apparent rebound in HRV after 13 days of reduced training load (average 45% reduction in weekly distance completed), there was also a slight reduction in HRV at the end of the staging camp as the competition approached. This apparent reduction in HRV towards the commencement of competition fell outside the normal variation during regular periodized training that may indicate a greater level of athlete preparedness. These results, seen for the first time in a Paralympic sporting environment, are supported by recent research (15) that documents a decrease in parasympathetic activity with an increase in sympathetic activity before the start of the competition.

Plews and colleagues (15) observed a similar reduction in HRV, albeit within the smallest worthwhile change, in the days leading up to a world championship rowing competition for Olympic champion rowers. It has been suggested that this increase in parasympathetic modulation with taper, coupled with a decrease in parasympathetic modulation near the end of a taper as competition approaches indicates an increased 'freshness' or 'readiness to perform' (15). The current results provide further support for this theory as all swimmers recorded personal best times during the Paralympic games. While previous studies have suggested that an increase in parasympathetic modulation during taper is ideal (1,7), Plews et al. (15) suggest that reductions in HRV in the days prior to peak events may signify a greater readiness to perform for elite athletes. The exact mechanism and benefits for the HRV reduction prior to competition are unknown, but appears to be triggered by the reduction in training volume (15).

Finally, this study highlighted the differences in HRV profiles between Paralympic swimmers with varying impairments. An athlete with a neuromuscular impairment displayed a significantly lower cardiac autonomic profile to athletes with either a major or minor amputation. In addition, the athlete with a neuromuscular impairment did not follow the same trend in HRV during the taper period.

Further, athletes with a major amputation showed a significantly reduced profile to the athletes with a minor amputation. Several studies (5,10) have suggested that individuals with an amputation may exhibit reduced parasympathetic modulation and a heightened sympathetic modulation resulting from the altered sympathetic activity of the residual limb that influences sympathetic impulse patterns and sympathetic-efferent outflow of vasoconstrictor fibers.

It is important to point out that for the first time in an athlete population, the findings in the present study document that the reduction in HRV is associated with the degree of amputation (5,10). Identifying the physiological mechanisms underlying the altered cardiac autonomic profiles of elite athletes with varying impairments may enable coaches and sport scientists to better manage the athlete's workload prior to competition. Understanding the differences in cardiac autonomic profiles for Paralympic athletes with varying impairments may also offer a better understanding of the benefits and limitations of HRV monitoring in an elite Paralympic sporting environment. However, it must be noted that these findings are based on the small sample size of Paralympians (N = 6) compared to what is typically published (6,8) and, therefore, may limit applicability to other disability types and Paralympic sporting classifications.

CONCLUSION

This study has documented for the first time daily HRV responses in elite Paralympic swimmers during a taper training phase prior to one of the most important international competitions. HRV followed a consistent trend reducing at days 2 and 3 that, then, peaked on days 11 to 14. This study has identified the HRV changes in the lead up to major competition, highlighting a slight reduction in HRV and potential athlete readiness. Significant differences were found between impairment profiles of athletes and highlighted the need for individualized programs. This unique finding may shed light on a significant physiological controller of HRV in the Paralympic athletes with differing disabilities. Further investigation is warranted to better understand how elite athletes with various disabilities respond during taper, thus allowing coaches to further enhance and individualize training workloads during the lead up to major competition.

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