EFFECTS OF RECOVERY WEAR ON HEART RATE VARIABILITY FOLLOWING THE WINGATE ANAEROBIC TEST

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAI'I AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN

KINESIOLOGY AND REHABILITATION SCIENCE
AUGUST 2012

By: Koichiro Gomyo

Committee Members:
Ronald Hetzler
Iris Kimura
Cris Stickley

We certify that we have read this thesis and that, in our opinion, it is satisfactory in scope and quality of a thesis for the degree on Master of Science in Kinesiology and Rehabilitation Science.

Thesis Committee

____

Chairperson

____

____

TABLE OF CONTENTS

PART I

INTRODUCTION

Rapid recovery from high intensity repeated of bouts exercise within short periods of time should be beneficial for athletes to enhance subsequent performance and prevent chronic overtraining injuries[1]. Accumulation of lactate is historically considered one of the important correlates of fatigue and blood lactate concentration has been used as an indicator of exercise-induced fatigue[2]. During anaerobic exercise, fast twitch muscle fibers (type IIa and IIb) are primarily recruited. Lactate is generated and hydrogen ions are released which decreases intramuscular pH[3,4], contributing to fatigue.

Active and passive recovery protocols are well known methods to enhance the return to homeostasis after the exercise. Numerous studies have shown that active recovery, which involves recovering from exercise via continuously engaging in exercise at low intensity, is the most effective method of decreasing blood lactate levels[5-14], but active recovery is not always feasible[10]. Active recovery increases blood circulation via vasodilation which facilitates the lactate buffering capacity and oxygen delivery to the muscles. Active recovery will also increase the metabolism of lactate by recruiting type I muscle fibers during the recovery period[11,13,14].

In order to facilitate rapid recovery, compression garments have been used during exercise and post-exercise recovery among athletes. Research involving theses garments are inconclusive [15-17] and have revealed little effect on recovery[18]. Specific warm-up/warm-down/compression garments have been developed to promote quicker recovery via choice of materials or fabrics. Compression garments are believed to facilitate post-exercise recovery by increasing peripheral venous return. Recently mixtures of nanoplatinum and nano-diamond coated materials (DPV576) have been applied to the garments to aid recovery.

One such garment was specifically designed to augment recovery from exercise via stimulation of the parasympathetic autonomic nervous system, whereby heart rate recovery (HRR) is enhanced[19]. Although untested, this may be possible as Katano et al. (2010) showed that bed padding made of DPV576-F materials effectively reduced stress symptoms (chromogranins A) in healthy adults. A reduction in stress should result in changes in the autonomic nervous function determined by assessing Heart Rate Variability (HRV). The autonomic nervous system controls the cardiovascular system[19]. Sympathetic tone is dominant during exercise to increase heart rate and blood pressure. Parasympathetic activity increases at rest and during recovery from high intensity exercise and it has been shown to be correlated with HRR[19-23]. A limited number of studies involving investigation of DPV576 materials suggested that this new material[24-26], DPV576 when coated on garments, may aid recovery or enhance subsequent performance. However, to our knowledge no studies have been published in which HRV has been used to investigate the effects of DPV576 on autonomic function after high intensity exercise.

The purpose of this study was to investigate the effect DPV576 coated recovery garments had on the parasympathetic system via Heart Rate Variability and Perceived Recovery Status scale after a high intensity anaerobic exercise.

METHODS

RESEARCH DESIGN

This was a single-blind experimental study with randomized trials. The independent variables consisted of group (experimental recovery wear (RW) and sham recovery wear (SW)) and data collection time period. Two, 2 x 5 Analyses of Covariance (ANCOVAs) with repeated measure (RM) were used to analyze HRV time domain and frequency domain data (covariate was peak power). Two, 2 x 6 ANOVAs with RM were used to analyze PRS and HR recovery. Four, 2 x 2 ANOVAs with RM were used to analyze the performance of the WAnT (mean power, peak power, minimum power, and percent decrease). Trend analysis using orthogonal contrast coefficients was applied to LF/HF data.

PARTICIPANTS

Thirty (n=30, 15 males, 15 females) healthy individuals, aged between 18 to 34 years old from University and surrounding community participated in this study. Participants' anthropometric data are presented in Table 1. Exclusionary criteria included pregnancy, neurological disease, cardiopulmonary disease, and exercise contraindications outlined by American College of Sports Medicine (Appendix B). An informed consent was obtained and consent form (Appendix A) approved by the University Institutional Review Board Committee on Human Studies was signed by all participants prior to the study.

Table 1. Male and Female Participant Demographics (mean ± SD) (n=30)

Gender	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m²)
Males (n=15)	23.7 ± 4.1	174.5 ± 7.3	74.3 ± 6.6	24.4 ± 2.2
Females (n=15)	23.2 ± 3.0	163.4 ± 7.1	58.3 ± 8.1	21.9 ± 2.9

BMI = body mass index

GARMENTS

All RW used in this study were provided by Venex Co., Ltd. (Kanagawa, Japan) The subjects were blinded as to which garments had the DPV576 materials. Experimental T-shirts and long tights consisted of polyester (with DPV576 fiber materials) and polyurethane. The sham garment consisted of polyester and polyurethane without DPV576 materials. Both garments were similar in appearance and texture with the labeled tag inside the garments to indicate the sham. Both garments were washed after each trial and used again for subsequent trials. Upon completion of this study, RW and SW were kept in the human performance laboratory for future study.

PROCEDURE

Experimental Protocol

All testing sessions were performed in the University's Human Performance Laboratory. All data were collected by Board of Certification athletic trainers. Upon arrival the subjects were given an informed consent form and Pre-Participation Medical History Form/ Physical Activity Readiness Questionnaire to complete that was screened for safe study participation by a medical doctor. The American College of Sports Medicine (ACSM) guidelines for contraindications and termination of exercise testing were strictly followed. An investigator walked through all testing procedures with each subject to familiarize them with the protocol. Anthropometric data, including body weight, height, and blood pressure, were collected and recorded prior to the each testing session. The electrocardiography (ECG) electrodes and leads were attached to subjects and the subjects were positioned supine on a treatment table and asked to relax for 20 minutes prior to start of WAnT1. The ECG was monitored throughout the 20 min relaxation period. The inter-beat intervals were recorded for last 5 min to determine HRV. The resting HR was measured prior to the WAnT1 using a heart rate monitor (Polar Heart Rate Monitor FT1 Wrist Receiver/ T31 Transmitter, Oulu, Finland). The RPE data were collected pre- and post-WAnT1. The subjects then performed 20 sec WAnT1[27] on a cycle ergometer. Immediately after a completion of the WAnT1, the subjects were instructed to change into either RW or SW as quickly as possible, and then asked to lie supine on a treatment table for a 30 min rest period. The perceived recovery status (PRS) scale[28] was taken every five minutes after exercise. Post-WAnT1 HR was also measured every five minutes post WAnT1[27] exercise in order to determine the heart rate recovery response. The ECG was monitored for 30 minutes of the rest period. The inter-beat intervals were collected continuously from five to 30 minutes post-exercise. After 30 minutes of recovery, the subjects were instructed to remove the garment and change into the original clothes they wore during the WAnT1. Then subjects performed a second WAnT followed by a five minute cool-down. In order to compare the two conditions, the subjects completed a total of two testing sessions which were separated by at least seven days. The garment application was assigned in a counter-balanced order and the subjects were blinded as to which garment they would be wearing.

Wingate anaerobic test protocol. A Monark Ergomedic 834E Cycle Ergometer (Monark Exercise AB, Vansbro, Sweden) was used during the repeated bouts of the Wingate anaerobic test (WAnT1 and WAnT2). The seat position was adjusted for each subject so at the bottom of each pedal stroke with the knee was near full extension with the foot in the neutral position. The handlebars were positioned for each subjects' comfort. All seat and bar position parameters were recorded for reproducibility for second testing session. Standardized instructions were read to all subjects prior to start the test. The subjects performed five minutes of pedaling at 70 RPM without resistance with cadence assistance from a metronome. At the end of the each minute of the warm up, the subject performed a practice four-to five-second sprint. The 20-second WAnT began with a three-second countdown by the investigator as the subjects begin pedaling as fast as possible. Next, a resistance weight (0.10 kp * body mass in kg) was quickly applied to the fly wheel, using the basket technique. The subjects were encouraged to pedal as hard and fast as possible for the entire 20-seconds test without pacing themselves. Power outputs were recorded every second throughout the 20-second test using a commercially available photoelectric data collection system (SMI Power 2000, ver.1.02; Sports Medicine Industries, Inc., St. Cloud, MN, USA). Ratings of Perceived Exertion (RPE) were collected using Borg's 6-20 RPE scale to assess the subject's perceived effort at the end of the each WAnT[29]. Immediately after the WAnT1, subjects were instructed to put on the pre-selected garment and ECG electrodes were applied after they changed clothes. The subjects then began the 30 min supine recovery period without an active cool down.

HRV collection protocol. Heart rate variability was evaluated twice (Pre and Post WAnT) for each subject in each testing session (total four times). The ECG data were collected using CARDIO-CARD ver. 5.54 software (Nasiff Associates, Inc., Brewerton, NY, USA), and time and frequency domain data were obtained using HRV Analysis ver. 2.0 software (Biomedical Signal Analysis Group, Dept. of Physics, University of Kuopio, Finland). The subjects were instructed to sit on a treatment table for electrode placement. Electrodes were placed on the palmar side of the wrists between ulnar and radial styloid processes and inferior to the 10^{th} rib along the midline of the nipple. The investigator cleaned electrode placement sites with an alcohol prep. The subjects were then instructed to lie supine and relax on a treatment table for 20 minutes for Pre-WAnT HRV measurement. Subjects were asked to breathe at their normal self-determined pace while the investigator collected and monitored the ECG. The subjects remained supine on a treatment table for 20 minutes and ECG was recorded for last five minutes. Once the ECG was successfully recorded, the ECG leads were removed by the investigator prior to start WAnT1. For the post-WAnT1 HRV measurement, the ECG leads were replaced on the same sites by the investigator. The investigator continued to monitor ECG throughout the 30 minute recovery period and record it from five minutes post-exercise until the end of the recovery period for 25 minutes. Once recording was completed, electrodes and leads were removed by the investigator. The investigator assessed and saved the data on the computer. The data were analyzed using the HRV analysis software which generated both time and frequency domain variables. Frequency domains were established using Fast Fourier Transformation (FFT) spectral analysis. Premature heart beats were eliminated by the investigator prior to the HRV analysis.

Recovery Wear application protocol. The type of the garment was assigned in a counter-balanced order by the investigator prior to the study. The size of the garments was determined based on the body size of the subjects. Upon completion of the WAnT1, the subjects were instructed to change into either RW or SW as soon as possible, then lie down supine on a treatment table. The treatment table was positioned next to a cycle ergometer. An experimental station was surrounded by the screens. As soon as the subjects completed the WAnT1, all investigators walked out the experimental station and walked back in the station when the subjects indicated they were changed and were ready to proceed. After 30 minutes of recovery period, the subjects removed the garments and changed into their original clothes before they started WAnT2. Each garment was collected after the testing session by the investigator and washed after each trial.

STATISTICAL ANALYSIS

Descriptive statistics and correlations were used to identify subjects' characteristics and PRS scores, respectively. Inferential statistics were used to identify differences in RW and SW relative to the following dependent variables: HRV time domain and frequency domain measures, HR recovery, PRS scores and WAnT performance. Data were analyzed by using SPSS version 19 (SPSS Inc., Chicago, Ill). Statistical significance was determined at $p < 0.05$ alpha level.

RESULTS

Heart Rate and Heart Rate Variability

Averaged HR data during recovery period for both conditions are presented in Table 1. No significant differences between garments were found for post-exercise HR. Averaged data for both time and frequency domain variables collected before WAnT1 and during 30 min recovery period are presented in Table 2and 3. No significant differences were found for HRV time and frequency variables between garments.

Table 1. Summary Table of Averaged Data for HR (Means ± SD).

	Condition	Resting	Peak HR	5min-post	10min -post	15min-post	20min-post	25min-post	30min-post	F-value	Sig.
HR	RW	60.1 ± 10.1	165.2 ± 10.0	86.3 ± 13.1	85.4 ± 12	83.7 ± 13.3	78.6 ± 12.2	76.9 ± 12.1	75.1 ± 11.3	0.852	0.514
	SW	63.3 ± 10.1	163.6 ± 9.9	87 ± 13.4	85.7 ± 12.9	81.3 ± 18.8	80.3 ± 12.7	77.1 ± 12.1	74.5 ± 11.2		

RW= Recovery Wear, SW= Sham Wear.

Table 2. Summary Table of Averaged HRV Time Domain Data (Means ± SD).

	Condition	Baseline	5min-post	10min-post	15min-post	20min-post	25min-post	F-value	Sig.
MeanRR (msec)	RW	1027.3 ± 143.7	704.8± 97.1	726.8 ± 108.3	755.4 ± 115.2	787.5 ± 122.3	805.7 ± 122.3	0.071	0.991
	SW	976.3 ± 150.7	703.5 ± 104.3	723 ± 104.5	753.1 ± 103.1	781.6 ± 103.2	798.3 ± 105		
SDNN (msec)	RW	63 ± 29	28.3 ± 10.9	26.9 ± 9.6	31.2 ± 11.3	36.8 ± 17.3	37.3 ±15.3	0.408	0.803
	SW	56.7 ± 25.2	26.7 ± 11.6	27.1 ± 10.3	29.6 ± 10.1	35.7 ±12.3	38.3 ±19.4		
rMSSD (msec)	RW	76 ± 39.2	31.9 ± 11.2	29.5 ± 11	33.1 ± 12.6	39.9 ± 21.9	37.5 ± 14.9	1.014	0.401
	SW	64.5 ± 35	32.8 ± 15	30.4 ± 12.3	30.6 ± 9.4	35.6 ±14.9	37.9 ± 21		
pNN50 (%)	RW	42.9 ± 19.4	12.1 ± 10.2	10.4 ± 9.9	12.6 ± 10.6	16.5 ± 13.6	15.6 ± 12	0.726	0.575
	SW	35.6 ± 19.2	11.2 ± 10.2	10.3 ± 9.7	10.7 ± 8	13.8 ± 9.6	15.8 ± 12.7		

RW= Recovery Wear, SW= Sham Wear, MeanRR= mean inter-beat intervals, SDNN= standard deviation of inter-beat intervals, rMSSD= the square root of the mean of the sum of the squares of differences between adjacent NN intervals, pNN50= NN50 count divided by the total number of all NN intervals.

Table 3. Summary Table of Averaged HRV Frequency Domain Data (Means ± SD).

	Condition	Baseline	5min-post	10min-post	15min-post	20min-post	25min-post	F-value	Sig.
LF Power (ms)	RW	1975.4 ± 2782.6	366.4 ± 345.6	349.3 ± 305.6	477.5 ± 361.8	745.2 ±784	763 ± 854	1.01	0.403
	SW	1447.5 ± 1189	246.7 ± 229.6	377.6 ± 357	503.3 ± 527.6	735.7 ± 563.6	947.7 ±1093.2		
HF Power (ms)	RW	2474 ± 2713.2	316.9 ± 302.3	257.5 ± 240.6	307.9 ± 242.3	554.2 ± 808	484.2 ± 419.2	0.414	0.799
	SW	2046.3 ± 3358.6	303.5 ± 339.4	273.7 ± 280.2	297.6 ± 244	456.7 ± 544.3	573.1 ± 1054.5		
LF Power (n.u.)	RW	44.2 ± 16.1	51.6 ± 14.7	55.7 ± 15.3	58.5 ± 14.9	58.7 ± 15.8	57.6 ± 17.4	1.539	0.192
	SW	48.7 ± 18.9	45.5 ± 16.4	55.4 ± 20.1	56.1 ± 22.5	62.3 ± 17.1	59.2 ± 21		
HF Power (n.u.)	RW	55.6 ± 16.1	47.8 ± 14.5	44.3 ± 15.3	41.3 ± 14.6	41.3 ± 15.8	42.1 ± 17.3	1.679	0.156
	SW	50.9 ± 19.2	54.5 ± 16.4	44.6 ± 20.1	43.9 ± 22.5	37.7 ± 17.1	40.8 ± 21		
LF/HF	RW	0.96 ± 0.7	1.3 ± 0.92	1.6 ± 1.3	1.8 ± 1.1	1.8 ± 1.3	1.8 ± 1.2	1.28	0.279
	SW	1.3 ± 1.2	1 ± 0.66	1.7 ± 1.2	2.1 ± 1.8	2.3 ± 1.7	2.2 ± 1.8		

RW= Recovery Wear, SW= Sham Wear, LF Power= power in low frequency range, HF Power= power in high frequency range, LF/HF= ratio LF [ms2]/HF [ms2].

Perceived Recovery Status

Table 4 presents the average scores of PRS scale. The scores with RW were consistently higher over the time. However, there were no significant differences for PRS (F=0.12, p=0.988). Table 5 presents correlations between PRS scores and selected HRV indices.

Table 4. Summary Table of ANOVA for PRS Scale Data (Means ± SD).

	Condition	5min post	10min post	15min post	20min post	25min post	30min post	F-value	Sig.
PRS	RW	4.8 ± 2.1	6.3 ± 1.8	7.4 ± 1.7	8 ± 1.5	8.4 ± 1.5	8.6 ± 1.3	0.132	0.982
	SW	4.4 ± 1.6	6 ± 1.9	6.9 ± 1.7	7.7 ± 1.6	8.1 ± 1.5	8.4 ± 1.4		

RW= Recovery Wear, SW= Sham Wear, PRS= scores of perceived recovery status scale.

Table 5. Summary table of correlation between PRS and HRV indices.

	PRS vs. rMSSD	PRS vs. HF Power	PRS vs. LF/HF
RW	r = 0.73	r = 0.69	r = 0.96
SW	r = 0.57	r = 0.74	r = 0.98

All correlations were significant, $p<0.01$

Performance of WAnT

The results of WAnT variables were presented in table 6. No significant differences were found between the conditions of the garment.

Table 6. Summary Table of ANOVAs for WAnT Data (Means ± SD).

	Condition	WAnT1	WAnT2	F-Value	Sig.
Mean Power (W)	RW	488.6 ± 146.7	491.2 ± 157.6	0.028	0.868
	SW	486.9 ± 145.7	490.9 ± 146.9		
Peak Power (W)	RW	610.3 ± 179.8	597.7 ± 189	0.021	0.885
	SW	599.8 ± 167.1	585.7 ± 167.9		
Min. Power (W)	RW	373.3 ± 134	391.6 ± 134	0.003	0.956
	SW	363 ± 156.6	382.3 ± 134.6		
% Dec.	RW	39.4 ± 10.4	34.7 ± 7.1	0.004	0.948
	SW	40.4 ± 15.7	35.4 ± 9.3		

WAnT1= first 20 second wingate anaerobic test, WAnT2= second 20 second wingate anaerobic test.

DISCUSSION

This study was conducted to assess the effect of DPV576 coated recovery garments on the parasympathetic system via HRV after a high intensity bout of anaerobic exercise. To our knowledge, this was the first study that involved investigation of DPV576 coated recovery garments using HRV. The most important finding of the present study was that there were no significant main effects or interactions between RW and SW garments during recovery in terms of autonomic nervous system activity after the 20 seconds WAnT1. Parasympathetic modulation significantly increased during recovery period ($p<0.001$), but was not significantly different between the trials. Although there was no significant main effects difference between garments, there were significantly different linear trends during recovery for LF/HF ratio between garments ($F=4.04$, $p=0.468$).

Data during the half hour of recovery period were similar to those reported by Javorka et al. (2002)[21], who studied a comparable population. In concordance with their study, HR decreased gradually in the present study, but did not return to pre-exercise values after 30 minutes recovery period. Time domain HRV indices are very similar between the studies in the magnitude and shape of the recovery curve. Additionally, natural log transformations for LF and HF power resulted in values that were similar in the magnitude and shape of the recovery curve to those reported by Javorka et al (2002)[21]. Therefore, data from the present study were judged to be reasonable indices of HRV during recovery.

In this study, HRV time and frequency domain were utilized to investigate the effects of DPV576 coated garments on parasympathetic activity. Kannankeril et al.

(2004) found that immediately post-exercise parasympathetic tone increased until four minutes and remained constant until 10 minutes[30]. Immediate autonomic change was not recorded in this study because our subjects needed to change into the garments after the 20 second WAnT1. Also, guidelines on HRV published in a report from the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996) suggested not collecting HRV until after five minutes post-exercise due to unstable data[31].

The manufacturer of the RW garments used in this study claimed that DPV576 coated garments should help to facilitate recovery from exercise induced fatigue by increasing parasympathetic nervous activity. Two HRV parasympathetic indicators, investigated in the present study, are HF power and rMSSD. These variables gradually increased throughout the recovery period regardless of the types of the garments. High frequency power is often interpreted as representing parasympathetic activity[19]. Low frequency power is often described as representing both parasympathetic and sympathetic activity; whereas the ratio LF/HF represents sympatho-vagal balance, allowing HRV to be used as an index of autonomic responsiveness[19]. Goldberger et al. (2006)[32] has shown that rMSSD can be used as an index of post-exercise parasympathetic reactivation. Data from the present study demonstrate that parasympathetic reactivation occurred during recovery (see Figure 2 and 3). This finding was similar to other previous studies, which reported an increase in parasympathetic drive after exercise[33-36]. As can be seen in Figure 2, HF power actually decreased after 10 minutes of recovery and gradually rose. This response has been previously reported by Takahashi et al. (2000)[37] and Javorka et al. (2002)[21]. It should be pointed out that the components of HRV provide measurements of the degree of autonomic modulation rather than the level of autonomic tone and the averages of modulations do not represent the average level of tone[31].

The ratio of LF/HF increased over the recovery period for both conditions indicating an increase in sympathetic control, although the linear trends were significantly different. This increase in sympathetic control was possibly due to the anticipation of second WAnT after the recovery time, or perhaps an uncomfortable resting position, as the subjects were instructed not to move during the recovery period to avoid ECG artifact. The trend line for the RW was a gradual positive slope compared to a steeper slope for the SW. Because of the increase of the parasympathetic activity seen in the present study (increased rMSSD and HF power), an increase in LF/HF ratio must represent an increase in LF power (Table 3). An increase in LF/HF ratio suggests an increased sympathetic activity during the recovery period (see Figure 1). An increase in sympathetic activity usually corresponds with an increase in HR, which was not seen during the recovery period. It has been previously shown that there is a relationship between changes in HR and changes in HF power, but no relationship between changes in HR and LF/HF ratio during the rest due to experimental activity[38]. Pierpont et al. (2000) revealed that autonomic recovery was slower after performing high intense exercise than after performing low or moderate intense exercise because sympathetic activation remained after exercise to contribute to tachycardia.

Figure 1. Changes in LF/HF during recovery period

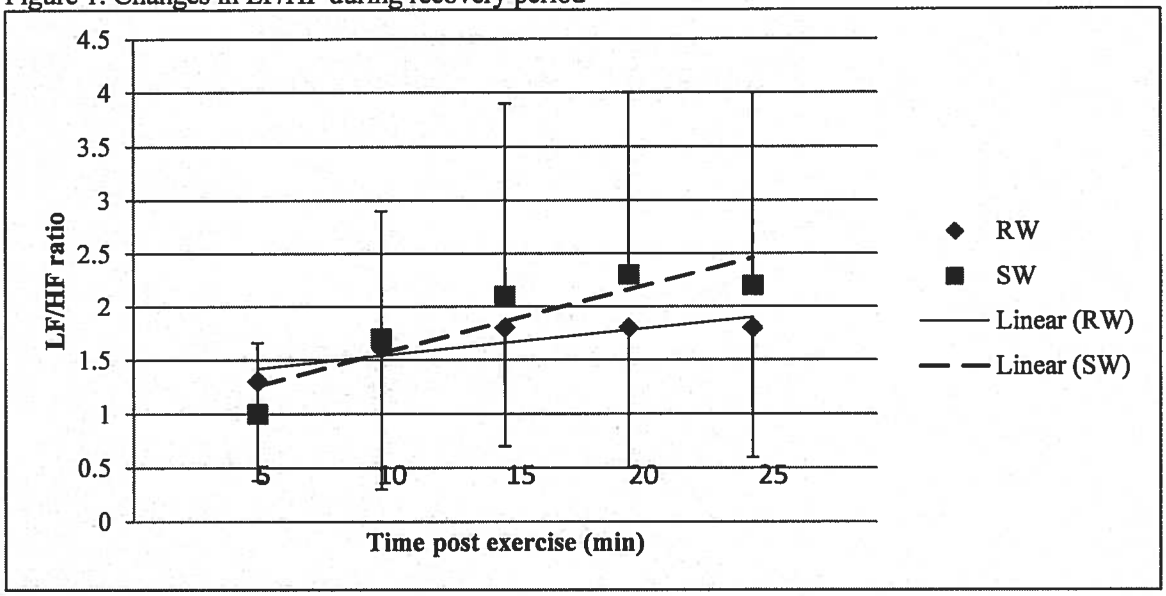


Figure 2. Post-WAnT1 changes in HF power (ms) in RW and SW

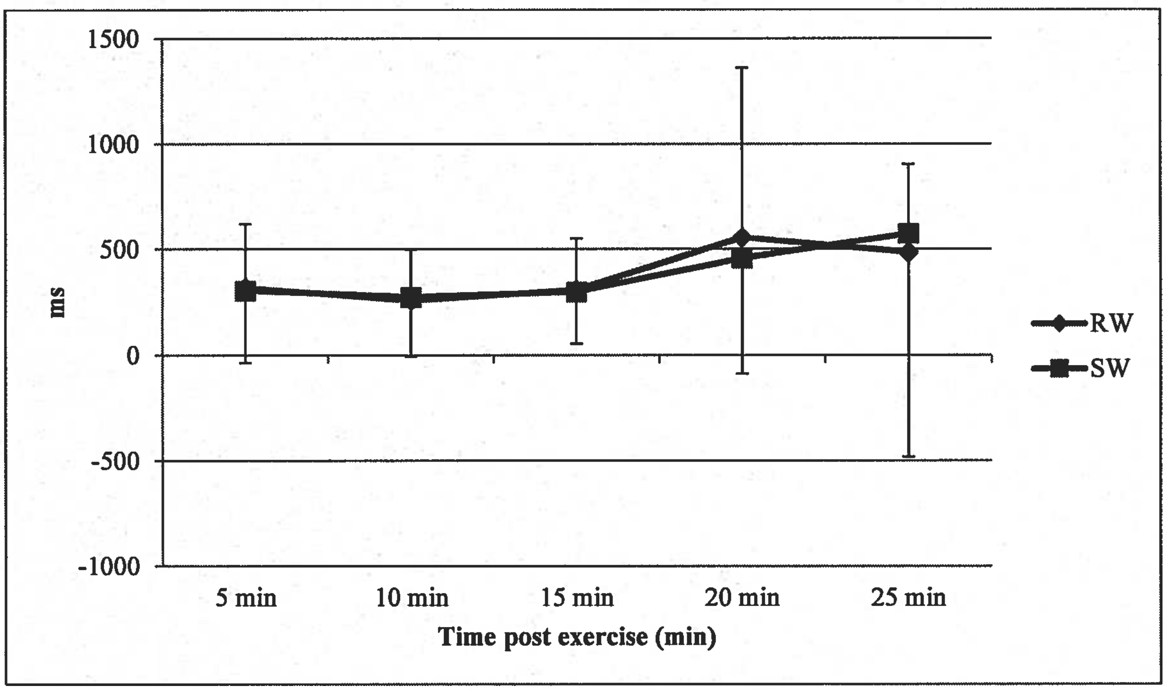
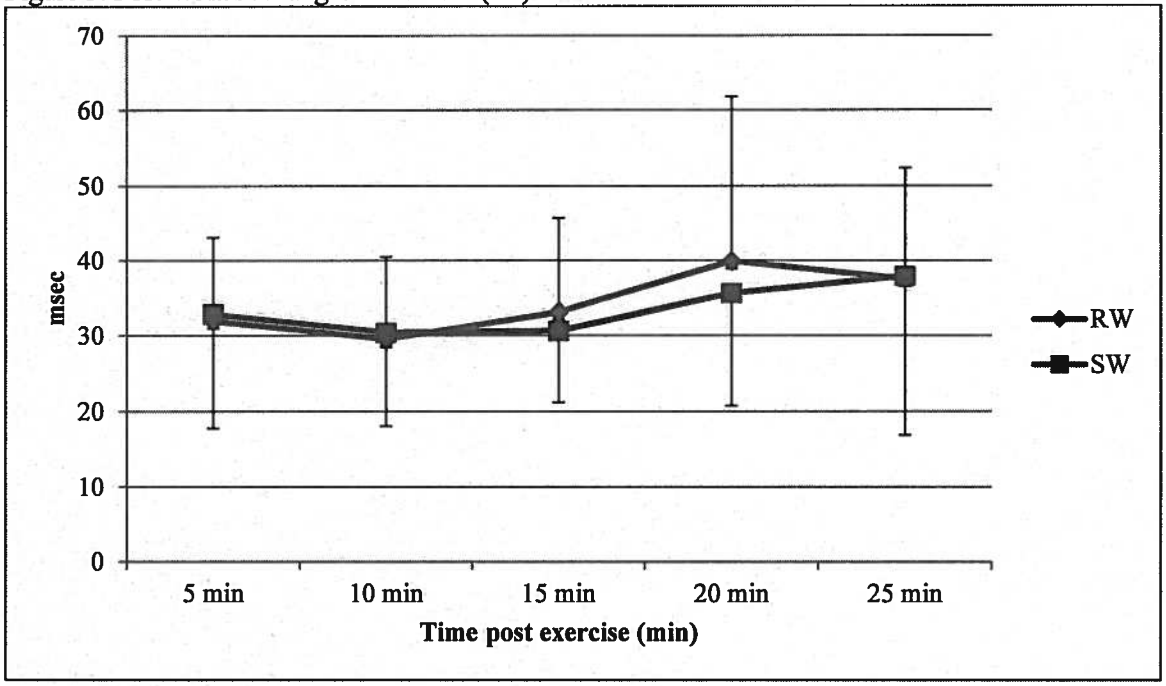
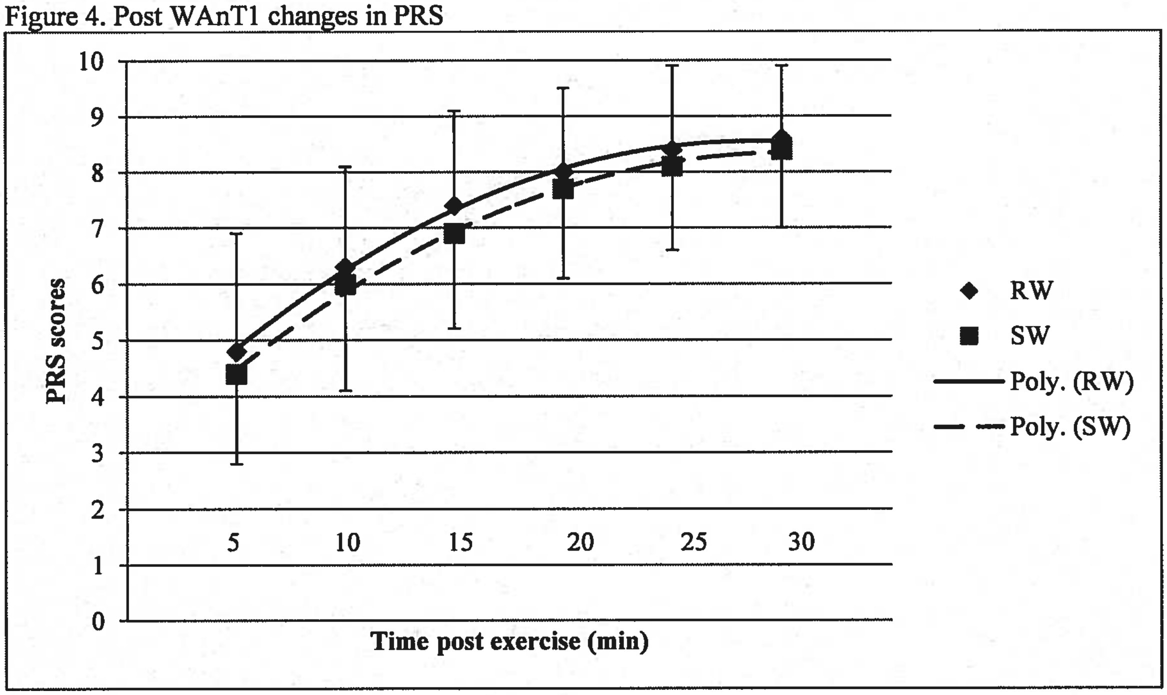


Figure 3. Post WAnT1changes in rMSSD (ms)



Laurent et al. (2011) created and assessed the practical utility of PRS scale to identify individuals' level of recovery after exercise. In his study, the subjects performed four bouts of high-intensity interval sprinting exercise protocols on four separate days with varying recovery time. Before each trial the subjects were asked to describe their recovery level using PRS. The level of recovery status was compared with changes in performance of sprinting exercise protocol. It revealed that there was a moderate negative correlation between the PRS score and the performance of sprint exercise protocol. The authors concluded that PRS may be beneficial to monitor individuals' recovery status after exercise. In the present study, PRS scale was utilized to identify recovery status at five minute intervals after the 20 second WAnT1. The scores of PRS gradually improved over the recovery period (see Figure 4) and were significantly correlated with indices of HRV (see Table 5). The average score of PRS 30 minutes after the WAnT1 was 8.5 (SD ± 1.4), which indicates that subjects were well recovered by the end of the recovery period. This is supported by the fact that there were no significant differences between the performance of WAnT1 and WAnT2 (Table 6). However, no significant difference for PRS was found between the conditions. It is interesting to note that high correlations were seen between the subjects' PRS scores and HRV indices associated with parasympathetic recovery and sympatho-vagal balance (Table 5). Thus the results from the present study support the validity of PRS scale.

Figure 4. Post WAnT1 changes in PRS



A limitation of present study was that the interval between a first testing session and a second testing session was longer than expected. Average numbers of days between the two testing sessions was 29 days (SD ± 16.0). This long interval may have changed subjects' fitness level, which would affect HRV data and the results of WAnT. In present study, repeated bouts of 20 second modified WAnTs were used in order to elicit sympathetic drive and induce physical fatigue. This protocol was selected because it was revealed to effectively predict the result of traditional WAnT and to decrease its side effects[27]. Post-WAnT RPE was taken for legs and joints, chest and breathing and overall readings to ensure subjects' maximal effort and exertion. Grand mean RPE scores were 13.9 (SD ± 2.2), 14.1 (SD ± 2.7), and 14.3 (SD ± 2.2) respectively. Subjects obtained 88% of the age predicted maximum HR value after WAnT1 based on the Gellish's second equation[39] which has previously been shown to accurately predict maximal HR in this population[40]. Although subjects achieved nearly maximum HRs after the 20 second WAnT1, this exercise test may have not caused fatigue especially for physically active subjects.

In summary, no significant differences were revealed for HRV time and frequency domain analysis between the DPV576 coated garment and sham garment. Within limitation of this study was concluded that DPV576 coated garment had no effect on HRV, HR recovery, PRS and performance of WAnT. It was also concluded that the PRS scale provides valid recovery status data based on HRV results.

PART II

REVIEW OF LITERATURE

Overview of fatigue and recovery

Traditionally, the level of lactate accumulation in blood has been clinically used as an index of fatigue[2]. During glycolysis, lactate and hydrogen ions are produced and decrease intracellular pH level[3,4]. Some lactates produced are then metabolized and utilized to facilitate glycogenesis[41].

Many studies have investigated different recovery methods used to facilitate recovery from high intensity exercise. Techniques such as active recovery, passive recovery and sports massage has been applied as recovery interventions following high intensity exercise[42].

Gupta et al. (1996) compared lactate elimination rate in active recovery (AR), passive recovery (PR), and massage after high intensity exercise trials (MR) in 10 well trained males. The purpose of the study was to study which recovery mode removed blood lactate more effectively after the supra-maximal exercise trials. The recovery mode consisted of resting for 40 min, pedaling a bicycle at 30% VO2max for 40 min or receiving a 10 min massage. Each recovery mode was randomly applied after each exercise trial. Researchers measured blood lactate (through the use of an automated lactate analyzer), gas exchange and heart rate. The most important findings included that lactate removal rate during AR was significantly higher than that of PR and MR. Higher HR was observed during AR. Researchers concluded that AR is more effectively facilitates quick lactate removal[11].

Monedero et al. (2000) also studied the effects of different recovery methods on lactate removal in 18 healthy male cyclists. The purpose of the study was to compare the effects of four different recovery methods including active recovery, passive recovery, sports massage and combination of active recovery and sports massage on lactate buffering capacity and subsequent performance. Prior to start the experiment, all subjects underwent VO2max test. All subjects performed two 5km maximal effort tests, which were separated by a 15 min recovery session. The recovery methods included the active recovery, passive recovery, sports massage, and combination of sports massage and active recovery. During active recovery, all subjects kept cycling at intensity of 50% VO2max. In passive recovery condition, the subjects rested on a chair. Massage was applied to their posterior lower legs by the same certified massage therapist. The combination condition consisted of 3.75 min of cycling at intensity of 50% VO2max at the beginning and the end, and 7.5 min of massage in between. All subjects underwent all four conditions. The most important findings included that combined recovery method significantly maintained performance of subsequent 5km maximal effort test, and active recovery and combined recovery method both significantly reduced blood lactate level after the exercises compared with passive recovery and sports massage. Researchers explained this result that combined recovery was the best recovery intervention because active recovery portion increased lactate removal rate and the glycogen restoration was facilitated during sports massage portion[43].

Studies have been done to investigate a mechanism of active recovery and effects of active recovery with different intensity and duration, and the influence to the subsequent performance. It is reported that active recovery effectively removes blood lactate and hydrogen ions concentrations and increases intracellular pH level by facilitating blood circulation and lactate buffering capacity through continuing low intensity aerobic exercise following high intensity exercise[6,8].

Sairyo et al. (2003) examined how active recovery at a decreasing work load influences the intramuscular metabolism. In order to measure intramascular energy metabolism in working muscle, Phosphorus-31 magnetic resonance spectroscopy (P31-MRS) was utilized. Seven healthy male performed isokinetic wrist flexion exercise at 60% of pre-determined maximum voluntary contraction (MVC) in P31-MRS system. After the exercise they had a 10 min recovery period. During the recovery period, participants randomly performed active recovery and passive recovery. In the active recovery protocol, participants initially performed isokinetic wrist flexion exercise at 25% of MVC. The exercise intensity was then decreased 5% every 2 min until it reached 5% of MVC. Inorganic phosphate (Pi) and phosphocreatine (PCr) were measured via 31P-MRS system because these values corresponded to the intracellular pH level [44]. The ratios of these two variables were used to calculate an intramuscular energy status. The statistical significant level was set at $P<0.05$.

Result showed that the Pi which dropped significantly during exercise increased following the exercise in AR ($P<0.05$). In contrast, it started to increase at 6 min post-exercise in PR. Active recovery increased Pi more than PR in 10 min recovery period. They found no significant difference in the ratio of Pi and PCr between AR and PR which indicating that intramuscular energy status returned to resting levels by the end of the recovery period in both AR and PR; with levels recovering more quickly during PR. This study suggested that Pi increases due to quick lactate removal facilitated by AR. Therefore, AR promotes intramuscular energy metabolism more effectively. Researchers concluded that future research is needed to investigate the effects of active recovery on subsequent performance[12].

Siegler et al. (2006) investigated the effects of passive recovery and active recovery on acid based response after repeated bouts of high intensity cycling exercise in ten male participants. All subjects underwent two experimental sessions, separated by one week. The experimental session consisted of three bouts of high intensity cycle ergometer interspersed with 12 min of recovery. Active recovery consisted of pedaling at 60RPM at intensity of 20% of maximal power output. During passive recovery, the participants were required to remain seated for 12 min. Blood samples were taken pre-, and post-exercises to measure blood lactate level. The most important findings from this study was that active recovery significantly improved blood acid-base recovery[13].

Del Coso et al. (2010) compared the effects of various active recovery protocols in 11 physically active male subjects. The purpose of the study was to investigate the effects of three different active recovery protocols on the rate of accumulation of hydrogen ions and lactate in blood. Two preliminary tests were performed a week before the experimental tests in order to obtain the lactate threshold and peak oxygen consumption and respiratory compensation threshold (RCT) for each subject. All subjects performed three experimental tests, which were separated by at least 4 days. The experimental test consisted of 4 bouts of high intensity cycling interspersed with one of the active recovery protocols, which included 4.5 min pedaling at 24% RCT (short), 6 min pedaling at 18% RCT (medium), and 9 min pedaling at 12% RCT (long). Blood samples were taken and measured to determine the concentration of hydrogen ions and lactate, CO_2 partial pressure, and plasma bicarbonate concentration. The most important findings included that the active recovery for 9 min at 12% RCT (long) significantly removed concentration of lactate and hydrogen ions from blood. Researcher concluded that active recovery with long duration and lower intensity could facilitate the buffering of blood lactate and hydrogen ions compared with the active recovery with short duration and high intensity[5].

Menzies et al. (2010) studied the removal of blood lactate during several varying exercise intensities after high intensity exercise bouts in 10 healthy male subjects. The purpose of the study was to assess the most effective exercise intensity during recovery to clear accumulated blood lactate from high intensity treadmill running. Researchers measured blood lactate, oxygen uptake and HR using Analox GM7 Lactate analyser (Analox, Hammersmith, UK), Servomex 4100 Gas Analyser (Servomex, Sussex, UK), Polar Heart Rate Monitor FS1 (Kempele, Finland) respectively. The most important finding from this study included that active recovery facilitated faster blood lactate removal and active recovery at higher intensity (60-100% of lactate threshold) was most effective at clearing blood lactate. Researchers concluded that active recovery at 80-100% of lactate threshold removed accumulated blood lactate most effectively[7].

Wingernaes et al. (2001) examined the effects of fifteen minutes of active recovery (AR) at 50% of maximal oxygen uptake (VO2max) on plasma free fatty acid (FFA), white blood cell count (WBCC), adrenaline, noradrenaline, insulin, and cortisol concentration after 60 minutes of running at 83% of VO2max. Thirteen healthy subjects randomly performed two trials of treadmill running followed by rest recovery (RR) and active recovery (AR) at 50% of VO2max for 15 minutes after the treadmill run. Blood samples were taken nine times in total during 120 minutes of post-exercise recovery period. All variables were individually analyzed. The data were analyzed by using SPSS and statistical significant level was set as $P<0.05$.

Result showed that concentration of FFA increased immediately after exercise in both RR and AR condition. However, FFA increased more rapidly in RR compared to AR. The WBCC increased during the running trials. In first 15 minutes of RR, WBCC significantly dropped ($P<0.05$) and started to increase to pre-exercise level, whereas WBCC stayed almost same level during 15 minutes of AR and gradually decreased after AR and increased back to pre-exercise level. After 45 minutes post-exercise, WBCC similarly increased in both condition and reached the initial level by the end of 120 minutes of recovery period. The number of neutrophil, lymphocyte, and monocyte significantly decreased after the exercise in both RR and AR condition. The count of neutrophil and monocyte came back to initial value by the end of the recovery time. Higher adrenaline and noradrenaline level was observed during AR. Insulin level decreased during the exercise and remained lower level during AR. Higher cortisol was detected during running and AR. This study showed that AR prevents exponential decrease of WBCC and FFA after the high intensity exercise[45].

Spierer et al. (2004) studied to verify the effects of active recovery and passive recovery on work performance during serial high intensity exercise trials in 6 sedentary subjects and 9 moderately trained subjects. All subjects performed repeated bouts of Wingate anaerobic tests separated by 4 min of recovery interventions including active recovery and passive recovery. The experimental sessions were separated by at least 3 days. Active recovery consisted of pedaling at intensity of 28% VO_2max. During passive recovery, the subjects remained seated on the cycle ergometer. Researchers measured blood lactate concentrations, HR, and peak and mean power and work from Wingate anaerobic tests. The most important finding from this study was that total work attained significantly increased during active recovery in both group of subjects. Fatigue was significantly decreased in sedentary group compared with trained group. Active recovery significantly reduced blood lactate level at 30 min after the Wingate anaerobic test in moderately trained group. Researchers concluded that further research is needed to determine the effects of recovery mode in clinical setting such as practices and games[14].

Bishop et al. (2007) investigated the effects of active and passive recovery on clinical setting in 8 males. The purpose of this study was to determine the effects of active and passive recovery from intermittent sprint exercise in hot environment. The subjects performed preliminary sessions including graded exercise test and familiarization with an intermittent sprint test. Intermittent sprint test consisted of repeated 4 seconds sprint on a cycle ergometer separated by 120 seconds of recovery. Active recovery consisted of 100 seconds of pedaling at an intensity of 35% VO_2max followed by 20 seconds of rest. During passive recovery, the subjects remained seated for 120 seconds. The intermittent sprint test was performed at 35°C, 44% relative humidity. Researchers measured temperatures, and plasma lactate concentration. A major finding of this study included that the difference in muscle and skin temperature between active recovery and passive recovery were greater. Researchers described that heat produced during active recovery in muscle was transferred to skin. Also greater muscle pump action during active recovery increased blood circulation and increased skin temperature. Researchers concluded that alteration of plasma lactate level was not observed although greater body temperature increase was observed in active recovery[9].

Numerous studies support the effects of active recovery and it has been shown to be beneficial recovery intervention following high intensity exercise. On the other hand, passive recovery is advantageous, if a short recovery time is allowed between repeated high intensity exercises[10].

Dupont et al. (2007) studied the effects of multiple recovery intensities on performance during two maximal anaerobic tests in 12 male subjects. The purpose of study was to evaluate the effects of recovery intensities during short recovery period using Wingate anaerobic test. All subjects performed three sessions of repeated Wingate anaerobic tests interspersed with different recovery interventions. The experimental sessions were separated by at least 2 days. The experimental session consisted of repeated Wingate anaerobic tests separated by 15 seconds of recovery. The recovery interventions included active recovery with intensity at 20% maximal anaerobic power (MAP), 40% MAP, and passive recovery. Researchers measured cardiorespiratory variables, lactate concentration, and change in tissue oxyhemogrobin and deoxyhemoglobin using the near-infrared spectroscopy. The most important findings from this study was that they found significantly higher peak power values and mean power of second Wingate after passive recovery. The value of deoxyhemoglobin at the end of second Wingate anaerobic test was significantly lower in a group which passively recovered in between two Wingate anaerobic tests. Researchers concluded that passive recovery was the more appropriate choice of recovery method, if there is short window for recovery in between repeated bouts of high intensity exercises[10].

Active recovery is not always the ideal recovery intervention, but the majority of literature shows that the effects of active recovery are beneficial. It is not the best recovery intervention when there is no time to cool-down or there is a short break time between the exercise sessions.

Compression garments/ Recovery wear

Compression garments have been used among the athletes and believed to enhance exercise performance and facilitate post exercise recovery. Several studies have been conducted to assess the effects of compression garments after exercise. These studies compared the effects of compression garments and other commonly used recovery interventions.

Gill et al. (2006) examined the effects four recovery interventions had on exercise induced fatigue through the measure of creatine kinase in 23 rugby players during post-game recovery.

Participants were randomly assigned to one of four recovery interventions: passive recovery, active recovery, compression garment, or contrast water therapy. The compression garment was worn for 12h. After the rugby match the subjects underwent one of the four recovery interventions. Creatine kinase activity was measured at immediately post-match, 36h and 84h post-match. The most important findings from this study included that the magnitude of recovery in active recovery, contrast water therapy, and compression garment was significantly greater than in the passive recovery. Significant difference in compression garment was not observed compared with active recovery and contrast water therapy. The researchers concluded that the combination of the three recovery interventions would be ideal method of post-match recovery[17].

Duffield et al. (2010) investigated the effects compression garments had on recovery after high intensity short distance sprint and plyometric exercises in 11 trained athletes. Participants performed 10 sets of a combination of 20m sprint and 10 double leg bounds with and without compression garment. Muscle torque was measured using an isokinetic dynamometer and blood samples were drawn pre-, 2h and 24h post-exercise to measure the concentration of metabolites in blood. The most important findings included that the compression garment had no effect on voluntary muscle performance during and after the exercise. The compression garment also had no effect on removing blood metabolites which were accumulated through the exercise. Some participants reported lower muscle soreness 24h after the exercise with compression garment, even though performance and physiological data showed no difference. The researchers concluded that the compression garment may help to reduce perception of muscle soreness following the exercise[16].

Similarly, Chatard et al. (2004) investigated the effects of the elastic stockings on leg pain and recovery following 5 min maximal exercise using cycloergometer in 12 elder subjects. Participants performed 2 sets of 5 min maximal cycloergometer exercise separated by 80 min recovery. They performed this exercise session 4 times in 2 weeks. During 80 min recovery the subjects were randomly assigned to either passive recovery group or elastic compression stocking group. In elastic compression garment group, they were applied the elastic compression stocking and they sat on a chair with their legs elevated. Blood samples were drawn to measure blood lactate concentrations and subsequent performance was compared with first maximal exercise. The most important findings included that the elastic compression stocking significantly decreased post-exercise blood lactate level compared with passive recovery. It slightly increased subsequent performance as well. The researchers concluded that the elastic compression stocking facilitated to remove blood lactate following maximal exercise and increased subsequent performance. Although this study showed the effectiveness of the compression stocking, there were a few limitations such as population of subjects, length of recovery and clinical applicability[15].

As a new type of the recovery garment, DPV576 coated recovery wear was introduced. DPV576 is a mixture of Nano-diamond and Nano-platinum and introduced by Venex Co., Ltd. (Kanagawa, Japan). It is reported that DPV576 coated material affects immune system and proliferation of T-cells[24,25]. However, none of the studies have investigated the effects of recovery wear on post exercise recovery.

The use of the compression garment is very popular among the athletes and believed to decrease fatigue and enhance performance. Literatures show little effect of the compression garment on recovery and performance.

Autonomic Nervous System and Exercise

During exercise, central command increases HR and cardiac output via vagal withdraw. Sympathetic nervous system dominates to increase HR as exercise intensity goes up[46]. Upon the termination of the exercise, parasympathetic nervous system is re-activated and sympathetic nervous system withdraws[19] which facilitates a decrease in HR, cardiac output, and respiration to resting level. Parasympathetic nervous system plays an important role in recovery from exercise. Studies have proven the correlation between the parasympathetic nervous activation and heart rate recovery (HRR) and HRV.

Javorka et al. (2002) determined the association between HRR, HRV and heart rate complexity after submaximal step test in 17 untrained males (age 20.3 ± 0.2 years, BMI 23.9± 0.5 kg/m^2). On the first visit, the subjects performed submaximal step test to predict their maximal power output. On subsequent visit, baseline ECG was taken before the step test. A step test at 70% of their maximal power output was then performed. Post-exercise ECG was taken as participants were instructed to position supine. Each baseline and post-exercise HRV was divided into five segments to be analyzed. Time domain and frequency domain variables were analyzed. Both time and frequency domain variables increased during recovery time following submaximal exercise test. Also, this study found that HR recovery was strongly correlated with HRV variables measured in recovery period. The researchers concluded that future research is needed to determine the cardiovascular parameters after exercise at different intensities[21]. Similar correlations were found following resistance exercise[20] and aerobic exercise[23].

Nunan et al. (2010) assessed the relationship between resting HRV and HR pre-, and post-exercise. The purpose of the study was to investigate the effectiveness of using resting HRV to predict HR response in 19 healthy males (range 20-63 years). A baseline HRV was recorded in supine position. All subjects then performed a graded exercise test. Post-exercise HRV was recorded for 10 min in seated position. Heart rate was measured pre-exercise, during exercise, and post-exercise. The authors of this study concluded that resting HRV was not well associated with post-exercise HR changes. However, post-exercise HRV and HRR was strongly correlated[22].

Literatures prove the strong relationship between HRV and HR. Heart rate variability has been proven to be the best method to investigate post-exercise HRR.

Perceived Recovery Status Scale

Laurent et al. (2011) created and assessed practical utility of perceived recovery status (PRS) scale to identify individuals' perceived recovery status after exercise. 18 moderately trained subjects (8 male, 8 female) participated to the study. The participants performed four trials of three cycles of eight 30m maximum effort sprint exercises on four separate days. PRS scale was utilized before each trial to assess the subjects' recovery status. Correlations between the PRS scores and change in performance of the sprint exercise were analyzed. Authors found that there were significantly ($p<0.01$) moderate correlations between the PRS scores and change in performance of the sprint exercises ($r = -0.63$). Authors concluded that PRS scale was practically beneficial to assess individuals' changes in performance and recovery status after exercise.

Appendix A:

Informed Consent Form **Participant ID**_____________

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Department of Kinesiology and Rehabilitation Science, University of Hawaii at Manoa

I. Investigator

Koichiro Gomyo, ATC: Iris F. Kimura, PhD, ATC, PT. Christopher Stickley, PhD, ATC, CSCS. Yukiya Oba, MS, ATC. Kinesiology and Rehabilitation Science Department. University of Hawaii at Manoa. 1337 Lower Campus Rd, Honolulu Hawaii 96822. Phone: (808) 956-7606.

II. Sponsor

VENEX Co., Ltd. 1-21-8 Asahicho, Atugi-shi, Kanagawa, 243-0014 Japan

III. Title

Effects of the Recovery Wear on HRV following the Wingate anaerobic test

IV. Informed Consent

I am being asked to participate in a study conducted through the University of Hawaii at Manoa because of your age and health status. The purpose of this consent form is to provide me with information about this research to help me decide if I would like to participate in this study. This form is called an informed consent form. If there are any words or sections in this consent form that I do not understand or want to clarify, I will ask the research staff to explain them. I will review this consent form and discuss any questions I may have with the research staff. If I understand the study and agree to take part in this study, I will be asked to sign this consent form.

It is important that I understand that taking part in this study is of my own free will. I may decide not to participate, or I may decide to drop out of the study at any time.

V. Purpose of the study

The purpose of this study is to examine the effects of the Recovery Wear (RW) after the Wingate anaerobic test (WAnT) on heart rate rhythm. The RW was introduced from Venex Co., Ltd. (Kanagawa, Japan). The garment contains nano-platinum and nano-diamond (DPV576) material fibers. The sham garment consists of polyester and polyurethane without DPV576 fiber materials. The company claims that RW facilitates relief of fatigue when it's worn after exercise by stimulating the autonomic nervous system (ANS). The ANS is a branch of the central nervous system that helps to adapt the body to outside stimuli and acts below the level of consciousness; it adjusts or modifies functions such as heart rate, blood pressure, etc. In order to compare the effects of the RW and sham, a total of two testing sessions will be conducted. The modified WAnT used in this study is an all-out 20 second sprint on a stationary bicycle that will be utilized to increase heart rate in a short period of time. The time between heart beats (inter-beat intervals) will be collected pre- and post-WAnT by electrocardiogram (pads on my chest) to determine the effect of RW on heart rate variability (HRV). Heart rate variability is measure of how the heart rate increases or decreases as I breathe in or out and can be used to investigate the ANS. A repeated bout of the 20 seconds WAnT will be performed in order to examine the effects of the RW on subsequent performance. The total amount of time I will be in this study is approximately 3 hours.

VI. Procedure
If I take part in this study, I will be one of a total of 30 people taking part in this study and I will have the following tests and procedures.

All testing sessions will be performed in the Human Performance Laboratory at University of Hawaii at Manoa. I will be asked to read and sign an informed consent form and complete a medical health history questionnaire upon a first visit. An investigator will walk through all testing protocols with all participants to make me feel comfortable performing the tests. Following anthropometric data will be then measured.

- Height (cm)
- Body mass (kg)
- Resting blood pressure

For the electrocardiogram (ECG), four electrodes will be applied one to each of my wrists and two will be to the lower chest area. I will lie on my back on a treatment table and relax for 20 minutes prior to start the first all-out 20 second sprint on a stationary bicycle (WAnT1). The ECG will be monitored throughout the 20 min period. The time between heart beats will be recorded for last 5 min to determine HRV. My resting heart rate will be measured prior to the WAnT1 using the heart rate monitor strap around my chest. I will then perform 20 sec WAnT1 on the stationary bicycle. The ratings of perceived exertion (RPE) scale will be taken pre-, and post-test to determine my perceived effort at the end of the test.

Immediately after a completion of the first WAnT, I will be instructed to change in a private area into either the RW or sham wear, and lie on my back on a treatment table and relax and rest for 30 min. The perceived recovery status (PRS) scale will be taken to determine how much I have recovered from the previous test at every 5 min post-exercise. Heart rate will be measured every 5 min post-exercise in order to determine the heart rate recovery response. The ECG will be monitored for 30 minutes of the rest period. The heart rate data will be collected from 5-30 min post-exercise. After 30 minutes of recovery, I will be instructed to remove the garment and change into original clothes I wear during the first WAnT. Then I will perform the second WAnT followed by a 5 min cool-down. In order to compare the two conditions, I will participate in a total of two testing sessions which will be separated by at least 7 days. Order of the garment application will be assigned by the research staff and I will not be informed which garment I am wearing.

Heart Rate Variability (HRV)
The time between heart beats will be collected pre and post WAnT to determine HRV.

Prior to the first WAnT, I will be asked to comfortably lie on my back and relax on a treatment table for 20 min. During this time, the investigators will clean the electrodes placement sites with an alcohol pad and scrub gel. The ECG electrode placement sites will be marked for post-test HRV measurement. Then the electrodes will be placed at palm side of my wrists and on below my last rib along the midline of the nipple to collect the inter-beat intervals. While I am lying on my back, I will be asked to breathe at self-determined normal pace. Once the inter-beat intervals are successfully recorded, the electrodes and leads will be removed by the investigator prior to start WAnT1. For post-WAnT1 HRV measurement the electrodes will be replaced on the same sites by the investigator. I will be asked to lie on my back on a treatment table and rest for 30 minutes. The investigator will continue to monitor my heart rate 5 min intervals throughout the 30 minute recovery. Once recording is finished, electrodes and leads will be removed by the investigator.

20 second Wingate Anaerobic Test (WAnT):
A stationary bicycle will be used for 20 second repeated bouts of the two WAnT. I will perform five minutes of pedaling at 70 RPM without resistance with cadence assistance from a metronome. At the end of each minute of the warm up, I will perform a 4- to 5-second sprint. The 20-second WAnT will begin with a 3-second countdown by the investigator as I begin pedaling as fast as possible. Next, a resistance weight will be quickly applied to the fly wheel. I will be encouraged to pedal as hard and fast as possible for the entire 20-seconds test. Peak and mean power, as well as percent decrease will be recorded every second throughout the 20-second test. Immediately after the WAnT1, I will be instructed to put on the garment and ECG electrodes will be applied. I will then begin the 30 min recovery period lying on my back without an active cool down.

Garment application
Immediately after the first WAnT, I will be instructed to change into either the RW or sham recovery wear in a private changing area.

The investigator may decide to remove me from this study if I:
- Decide not to participate in this study
- Cannot perform the WAnT
- Cannot continue the procedures due to side effects from the initial WAnT
- Get injured during the test

I may stop participating in this study at any time.

VII. Risks
There are slight risks associated with the WAnT. I may experience nausea, vomiting, dizziness, fainting, discomfort, and soreness after WAnT. The risks from taking the ECG are quite low. However, I may have temporary skin reactions such as itch, redness, and slight bruise where the electrodes are placed. The research may involve risks to subject that are currently unforeseeable.

VIII. Research Related Injury
In case of any physical injury during this study, immediate medical treatment including first aid, CPR and, an automated external defibrillator (AED) are available on site. If I am injured as a result of being in this study, immediate on-site care is available for my injuries. In the unlikely event of a medical emergency, First Aid/CPR will be provided and the emergency medical system will be activated. I understand that if I am injured in the course of this research procedure, I alone may be responsible for the costs of treating my injuries. The cost for this treatment will be charged to my insurance company or to me. My insurance company may not pay for these costs. If my insurance company will not pay for these costs, they will be my responsibility. The University of Hawaii has no program to pay you or compensate you in any way for your injuries. For possible research related injury outside the visit, please contact Koichiro Gomyo at (812)236-2432.

IX. Benefits
I may not directly benefit from this study although I can gain knowledge and experience from being part of this study. The result of this study may help athletes and others recover from exercise more quickly and safely.

X. Safeguard
I will be monitored closely by health care providers (Board Certified Athletic Trainers) while I am in this study.

XI. Confidentiality
All my research information will be kept confidential to the extent allowed by law. My personal information will not be given to anyone without my written permission. However, the University of Hawaii Committee on Human Studies has the right to review research records. A code, which will be known only to research personnel, will be used instead of my name on medical records in this study. Research records that may be identifiable to me will be kept in a secure locked file in the Department of Kinesiology and Rehabilitation Science at the University of Hawaii at Manoa.

XII. Compensation
I will receive no compensation (direct or implied) for completing this study.

XIII. Biological Specimens
I will not be asked to provide my biological specimens such as blood, saliva, and urine in this study.

XIV. Certification
Participation is voluntary; refusal to participate will involve no penalty to me. No reimbursement for parking is available and I will not be compensated for my time. There are no additional costs to participants associated with the research. There are no alternatives to the procedures in this study. I may withdraw my consent and discontinue participation in this research project at any time without negative consequences. I have the right to ask questions concerning the procedures at any time and have any questions answered to my satisfaction. If any new findings are developed during the time that I am

in this research project which may affect my willingness to continue to be in the study, I will be informed as soon as possible. All testing will be scheduled at my convenience when I am on campus. If I desire further information about this research project, I may contact Dr. Iris Kimura at (808) - 956-3797. If I would like to talk with someone about my rights of being a subject in this study I may contact the UH Committee on Human Subjects at (808)-956-5007, or by email: uhirb@hawaii.edu.

Informed Consent Form **Participants ID___________**

"Effects of the Recovery Wear on HRV following the Wingate anaerobic test"

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Department of Kinesiology and Rehabilitation Science, University of Hawaii at Manoa

I understand that if I am injured in the course of this research procedure, I alone may be responsible for the costs of treating my injuries.

By signing below, I certify that I have read and understand this informed consent form and all my questions have been answered to my satisfaction. I am aware of my rights and I choose to participate in this research project.

Printed Name of individual participant Date

Signature of individual participant Date

I have explained and defined in detail the research procedure in which the participant has agreed to participate and have offered him a copy of this informed consent form.

Printed Name of individual participant Date

Signature of individual participant Date

Appendix B:
American College of Sports Medicine's Guidelines for Exercise Testing and Prescription, 7th Edition Contraindications to Exercise

Absolute

- A recent significant change in the resting ECG suggesting significant ischemia, recent myocardial infarction (within 2 days), or other acute cardiac event
- Unstable angina
- Uncontrolled cardiac disrhythmias causing symptoms or hemodynamic compromise
- Symptomatic severe aortic stenosis
- Uncontrolled symptomatic heart failure
- Acute pulmonary embolus or pulmonary infarction
- Acute myocarditis or pericarditis
- Suspected or known dissecting aneurysm
- Acute systemic infection, accompanied by fever, body aches, or swollen lymph glands

Relative

- Left main coronary stenosis
- Moderate stenotic valvular heart disease
- Electrolyte abnormalities (e.g., hypokalemia, hypomagnesemia)
- Severe arterial hypertension (i.e., systolic BP of >200 mm Hg and/or a diastolic BP of >110 mm Hg at rest)
- Tachydysrhythmia or bradydysrhythmia
- Hypertrophic cardiomyopathy and other forms of outflow tract obstruction
- Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
- High-degree atrioventricular block
- Ventricular aneurysm
- Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxedema)
- Chronic infectious disease (e.g., mononucleosis, hepatitis, AIDS)
- Mental or physical impairment leading to inability to exercise adequately

1. Relative contraindications can be superseded if benefits outweigh risks of exercise. In some instances, these individuals can be exercised with caution and/or using low-level end points, especially if they are asymptomatic at rest.

Appendix C
Perceived Recovery Status (PRS) Scale

At 10, 20, and 30 min post-garment application, we will ask you to rate your recovery status, according to the PRS scale. You will be asked to choose a number to describe how much you have recovered from the previous Wingate anaerobic test. A rating of "8-10" would correspond to those feelings and sensations that you are well recovered and can expect better performance on subsequent exercise test. A rating of "4-6" corresponds to the feelings and sensations that you are moderately recovered and would expect similar performance on the subsequent exercise test. A rating of "0-2" would correspond to those feelings and sensations that you are not recovered at all and would expect declined performance on subsequent exercise test.

Please tell the number that you feel is appropriate.

10	Very well recovered/ Highly energetic	Expect Improved Performance (8–10)
9		
8	Well recovered/ Somewhat energetic	
7		
6	Moderately recovered	Expect Similar Performance (4–6)
5	Adequately recovered	
4	Somewhat recovered	
3		
2	Not well recovered/ Somewhat tired	Expect Declined Performance (0–2)
1		
0	Very poorly recovered/ Extremely tired	

Appendix D:

Pre-Participation Medical History Form/ Physical Activity Readiness Questionnaire

Participant Information

ID number ____________________

Date of Birth:________________ Age (years) _________ Sex: M / F

Home Address:___________________________________

City/State/Zip:______________________________ Email: ______________________

Home/Cell Phone (___) _______________

Emergency Contact Person/Relationship/Phone Number:

____(___)_______________

Physical Activity Readiness Questionnaire (American College of Sports Medicine, 1997)

Please read the questions carefully and answer each one honestly.

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem (ex. back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (ex. water pills) for your blood pressure or heart condition?
☐	☐	7. Do you know of any other reason why you should not do physical activity?

Medical History: the subsequent sections were obtained following guidelines for exercise testing (American College of Sports Medicine, 2005).

A. History: please check the box any condition you currently have or had in the past.

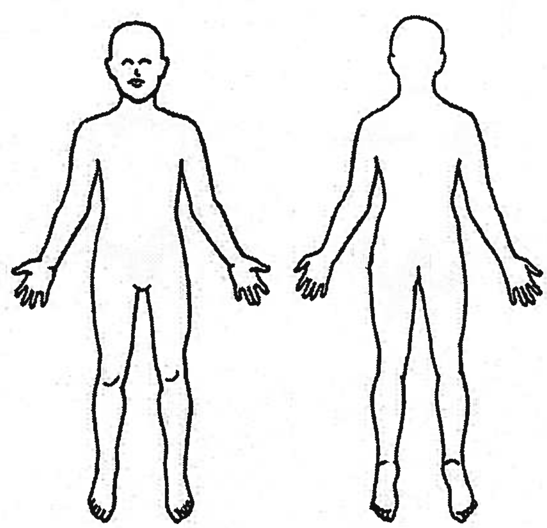
- ☐ Heart Attack
- ☐ Heart Surgery
- ☐ Cardiac Catheterization
- ☐ Coronary Angioplasty (PTCA)
- ☐ Pacemaker/implantable cardiac
- ☐ Defibrillator/rhythm disturbance
- ☐ Heart valve disease
- ☐ Heart failure
- ☐ Heart transplantation
- ☐ Congenital heart disease
- ☐ Diabetes
- ☐ Asthma
- ☐ Lung Disease
- ☐ Heart murmur
- ☐ Seizures
- ☐ Head injury or concussion
- ☐ Loss of consciousness or memory

B. Symptoms: please check the box for any symptoms you have or had experienced at rest, during or following exercise.

- ☐ Chest discomfort
- ☐ Cough or wheezing
- ☐ Dizziness, fainting, or blackouts
- ☐ Difficulty breathing
- ☐ Abnormal heart beats

Musculoskeletal Symptoms: please check the box for any symptoms you have or had experienced, locate and label the occurrence of each symptom on the figure below.

- ☐ Numbness
- ☐ Tingling
- ☐ Pain
- ☐ Swelling
- ☐ Burning
- ☐ Cramping



Appendix E:
Ratings of Perceived Exertion (RPE) Scale
RPE (modified Borg RPE Scale, Borg, 1998)

At the beginning and end of the test, we will ask you to rate the work, according to the RPE scale. You will be asked to choose a number to describe how hard the work is for you. A rating of "6" would correspond to those feelings and sensations you have during the easiest work you can imagine, similar to sitting in a chair. A rating of "20" corresponds to the feelings and sensations you would have during the most difficult work you could imagine yourself doing, so exhaustive that you cannot continue.

We will ask you to give local muscular ratings for perceived exertion and feelings of strain in the legs and joints; central readings which are sensations involving the chest and breathing; and overall readings, for which you may integrate the local and central sensations in the way you feel appropriate. Please point to the number that you feel is appropriate.

RPE Scale

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Appendix F:
The Wingate anaerobic test (WAnT1) Standardized Instruction

You will be asked to perform the 20 second modified Wingate anaerobic test. Prior to start the test, you will have five minutes of warm-up at 70 RPM without resistance with cadence assistance from a metronome. At the end of each minute of the warm-up, you will perform a 4- to 5-second sprint. You will have a couple minutes of rest before you start the Wingate anaerobic test. The 20-second Wingate anaerobic test will begin with a 3-second countdown by the investigator as you begin pedaling as fast as possible. Next, a resistance weight will be quickly applied to the fly wheel. You will be encouraged to pedal as hard and fast as possible for the entire 20-second test without pacing yourself. Immediately after the Wingate anaerobic test, you will get off the bike and put on the garment and lie on your back on the treatment table. Once you are changed and laid on the treatment table, you will say "I am ready" to indicate you are ready to proceed.

APPENDIX G:
Data Collection Sheet

Subject ID:_____________ Gender:________ Testing Session: 1 2 Type of Garment: RW SW Size:_____

Body mass (kg)__________ Height (cm)_____________ BP_____/_____ Ergometer seat height____________

Room temp_____________ Time of the day__________ am____ pm___

HRV (Baseline)	WAnT I	Put on RW	Post-WAnT HRV	WAnT II
Resting HR:_____	Pre-WAnT RPE:________ Post-WAnT RPE:________ Peak HR:___________	Change:________ ECG:________	HR5min post:_______ HR10min post:_______ HR15min post:_______ HR20min post:_______ HR25min post:_______ HR30min post:_______ PRS5__________ PRS10__________ PRS15__________ PRS20__________ PRS25__________ PRS30__________	Pre-WAnT RPE:_________ Post-WAnT RPE:_________ Peak HR:____________

Total time of the study:______________

Data Recorded by______________

APPENDIX H:
HRV Raw Data

Appendix: H-1 Raw Data for Mean RR with RW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	839.8	618.8	627	649.2	667.3	686.1
2	1049.5	876	924.7	929.7	951	948.5
3	958.1	624.3	634.3	652.1	683.1	704.7
4	949.9	656.4	678.5	690.3	735.9	736.1
5	944.3	683.4	676.3	730.7	808.2	838.7
6	941.5	649.3	679.7	733.3	771.7	820.8
7	1139.5	804.5	850.2	872	901.4	899.6
8	1051.8	643.3	650.2	673.3	689.1	713.1
9	894.3	776.1	802.4	847.4	865.4	801.5
10	1072.2	670.4	713.9	768.3	774.8	788.2
11	1203	741.4	820	887.1	930.9	962.2
12	717.2	547.3	573.8	579.4	625.6	633.8
13	1063	663.8	662.4	677.6	696.2	704.2
14	934.1	589.6	594.1	559.3	600.5	623.4
15	1150.7	658.6	671.5	684	711.1	771.5
16	1383.6	690.3	698.9	813.1	990.2	1075.5
18	1152.4	804.6	809.9	870.5	903.3	908.1
19	798.8	563.4	561.4	555.4	568.4	594.2
20	965.1	630.2	641.8	659.3	677.7	721.1
21	1145.2	612.4	664.5	662.5	683	719.8
22	1089.4	754.4	804.7	835	892.7	934.2
23	1218.2	919.4	918.9	932.5	941.4	958.9
24	1206	914.5	991	1003.8	1042.2	1013.6
25	1105.7	748.2	757.2	805.7	822.7	812.7
26	1122.1	742.9	823.9	832.1	876	895.4
27	994	778	776.7	784.2	805.8	826.6
28	988.1	647.3	644.5	669.5	680.3	701.9
29	899.2	706.8	709.6	747.5	781.5	794.2
30	843.9	791.4	801.7	844.6	832.6	858.7
31	999.1	636.3	641.4	713.5	713.8	723.8

Appendix: H-2 Raw Data for Mean RR with SW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	812	659.1	665.5	697.5	717.8	733.8
2	1133.6	811.4	834.3	870.6	878.4	919.6
3	1001.2	702.9	719.7	781.2	800.9	792.7
4	1009.9	751.4	802.7	824.7	860.3	823.8
5	1088.4	894.9	900.1	887.1	895.2	936.3
6	976.1	624.8	668.8	763.7	764.9	787.7
7	1176.8	762.6	784.8	805.3	838.7	889.8
8	932.7	635.5	677.8	684.7	706.3	715.9
9	903.1	771.6	832.7	827.5	862.6	898.3
10	1068.6	646.6	662	684.9	731.5	779.1
11	902.7	624.7	654.6	686.2	728.4	787.8
12	807	512.2	503.7	533.8	554.6	591.5
13	661.1	573.2	579.8	613.4	620.8	633.4
14	836.8	604.9	623.6	637	678.6	711.8
15	1034.8	693.9	702.3	734.5	782.7	812.4
16	1368.5	685.6	723	753.9	860.1	920.2
18	977.9	776.2	714.3	806.1	848.7	827.7
19	772.3	621.2	661.8	638.6	666.4	649.2
20	750.7	595.9	613	641.9	650.8	674.5
21	969	602.5	615.2	612.9	635.1	638.1
22	935.3	672.8	719.9	758.1	801.5	819.4
23	1152.9	975.9	957.1	971.7	985.6	995.3
24	1184	772.8	858.4	889.2	896.5	907.9
25	802.2	642.4	657.4	719.7	737.6	753.7
26	1070.8	786.5	814.9	845.5	858.8	884.7
27	1033.9	771.1	770.7	825.7	862.4	891
28	1015	647	669	678.5	725.6	709.8
29	880.4	664.8	662.3	706.8	726.6	709.9
30	985.6	894.7	903.5	908.2	944.4	904.3
31	1044.5	724.6	737.3	805.1	826.7	849.9

Appendix: H-3 Raw Data for SDNN with RW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	32.5	14.6	14.2	15.3	16.2	22.4
2	40.6	46.5	34.4	41.5	43.8	58
3	52.8	16.6	17.2	27.2	48.7	32.2
4	61.3	22.7	27.2	26	28.6	32
5	56.4	26	21.7	26.4	40.1	47.9
6	85.7	31.5	20.8	27.1	35.7	46.7
7	80.7	43.4	36.6	50.5	90	55.1
8	63.4	16.8	17.8	21.1	22.2	26
9	35.6	23	22.8	29.5	31.3	26.8
10	93.3	24.9	33.8	38.3	36.6	34.6
11	128.8	21.3	24.4	27.1	32	32.5
12	29.7	12.8	14.1	15	19.6	23.2
13	108.4	17	18.3	17.8	18.4	21.2
14	81.3	16.4	17.3	22.4	18.7	22.2
15	39.2	18.7	15.3	17.9	19.2	23.1
16	36.4	38.4	28.6	51.7	80.5	91.4
18	56	19.4	25.7	40.6	36.8	38.6
19	41.2	17.9	20.2	18.1	20.2	18.2
20	116.7	38.3	40.6	43.9	48	48.7
21	79.8	18.9	20.8	20.7	28	29.8
22	67.4	46.3	45.1	40.5	51.7	57.1
23	43.4	43.5	41	40.4	42.4	35.7
24	43	44.2	33.6	44.8	35.1	44.3
25	52.4	30	28.9	30	34.6	43.1
26	65.9	39.8	50.3	53.4	57.6	47.5
27	43.2	30.6	28.2	25.6	20.7	23.7
28	131.6	23.2	17.2	19.4	22.9	25.1
29	40.7	31.4	32.3	30.7	41.1	39.6
30	38.8	42.1	35	34.1	37.4	34.5
31	44.4	31.8	23.9	39.5	45.9	36.4

Appendix: H-4 Raw Data for SDNN with SW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	37.6	18.2	23.9	31.2	25.6	28.5
2	55.9	56.3	48.3	32.2	57.8	22.6
3	49.7	32.7	30.9	35.8	41.3	38.8
4	62.6	21.1	30.6	42.4	39.4	40.1
5	86.6	51.7	46	40.8	38.8	54.2
6	91.3	19.5	27.2	31	34.4	37.3
7	51.9	22.2	30.2	30.9	39.4	43.5
8	36.6	19.3	21.6	25.1	37.7	37.3
9	37.6	37.3	26.6	33.9	44.6	50.5
10	105.8	18.5	16.7	21.8	29.8	45.1
11	56.5	16.6	18.6	32.8	43.7	29.9
12	49.2	13.1	12.2	13.3	14.1	14.7
13	18.7	14.9	15.7	14.3	17.6	17.1
14	61.5	18.8	19.8	24.1	27.4	34.1
15	40.4	20.9	21.7	22.2	28.7	23.8
16	33.5	37	31.2	28.7	45	78.5
18	62.7	20.8	22.1	25.9	31.8	28.1
19	32.6	17.9	21.5	24.6	25.2	23.2
20	29.4	18.6	13.6	15.2	20.5	23.7
21	72	18.2	20.2	21.9	25.6	23.2
22	78.7	31.6	41.4	49.3	49.4	56.1
23	63.8	38.9	39.5	34.8	38.4	38.9
24	39.6	25.8	29	24.1	26.8	25.3
25	42.1	20.1	18.9	23.1	26.4	31.5
26	60.1	44.7	47.2	44.1	58.6	50.3
27	42.2	21.5	21.9	21.3	28	24.1
28	139.6	18.4	19.1	20	28.1	23.3
29	46.7	25.2	22.3	27.6	33.5	37.6
30	42.2	42.8	45.2	43.6	49.6	59.2
31	73.4	38.9	32.1	52.9	65.2	108.3

Appendix: H-5 Raw Data for rMSSD with RW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	33.9	18.1	17.6	20	20.2	32.5
2	52.2	48.6	39.7	43.7	48.8	57.1
3	55.7	21.2	20.7	30.6	67.2	29.4
4	73.1	25.8	25.2	24.8	28.7	28.9
5	59	24.1	22.5	25.9	36	42.6
6	98.5	40.7	22.9	25.1	28.7	36.3
7	91.7	44.4	41.5	54.3	120	64.9
8	68.8	22.3	22.3	21.8	22.3	23.4
9	35.4	25.7	25	28.8	32.2	26.2
10	96.1	25.6	28.5	34.6	31.2	35.6
11	164.3	24.7	24.5	26.1	31.1	32.5
12	26.2	17.5	19.6	18.6	21.4	22
13	142.4	22.6	23.1	21.5	23.3	24
14	97.4	20.3	21	20.5	21.9	24.5
15	53.5	25.2	21.3	21.4	23.9	23.2
16	40	32	24.7	45.5	75.8	77.1
18	67.8	21.8	24	30	30.8	32.7
19	46.8	22.5	19.4	19.7	19.5	18.8
20	149.5	48.1	62.5	67.3	68.4	66.2
21	101.3	22.4	24.2	24.5	27.1	32
22	94.3	50.5	43.7	41.7	58.7	64.5
23	71.3	58.2	51	58.6	61.1	50.1
24	53.9	43.9	39.7	40	37.6	40.8
25	65.2	32.7	27.6	33.7	33.1	33.9
26	76.5	44	49.8	45.2	43.9	37
27	59.8	36.1	31.9	29.8	24.4	29.3
28	177.2	29.1	20.1	23.9	26.9	28.2
29	47.6	41.9	30.8	30.8	39.1	39.1
30	40.8	37.3	33.9	39.5	39.6	41.1
31	39.7	31	25.9	46.4	53.8	30.9

Appendix: H-6 Raw Data for rMSSD with SW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	34	21.6	22.5	25	23.2	23.8
2	61.3	86.6	68.1	50.9	81.6	25.5
3	62.6	46.3	40.9	36	43.4	45.7
4	81.4	27.4	38.8	40	39.8	41
5	100.2	54.3	48	41.2	43.8	46.2
6	107.5	23.4	28.2	28.5	31.5	38.2
7	64.6	24.3	27.2	26.4	30.9	35.1
8	39.9	22.5	22.8	23.4	25.5	26.2
9	31.2	44.4	27.1	32.3	34.8	36.8
10	121.4	24.8	22.2	26.2	30.7	39.6
11	47.4	20.9	20.7	25.1	28.4	27.3
12	42.2	18.4	17.2	18.1	18.5	18.4
13	22.2	21.8	20.7	20	21.8	21.8
14	62.1	21.9	24.7	27.3	29.4	33.1
15	45.4	26.2	25.7	28.1	26.5	26.4
16	42.9	46.2	25.7	24.7	41.8	77
18	51.4	23.8	21.5	23.9	26.9	27.7
19	37.3	21.6	23.4	22.7	24	23.1
20	33	28.8	19.7	20.5	23.7	28.4
21	86.5	22.3	21	22.8	24.8	24.1
22	68.7	37	38.1	42	41.1	44.9
23	92.3	55	58.8	55.5	58.2	59.8
24	50.4	23.6	26.1	26.7	27.7	26.2
25	37.9	23.5	21.3	25.8	27.4	29.9
26	62.6	45.4	47.3	38.8	41.5	39.2
27	43.3	29.3	28.6	26.5	32.6	33.6
28	185.8	26.5	24.9	26.3	33.7	29.5
29	50	27.9	23.6	28.3	29.4	30.7
30	48.6	48.7	42.9	42.1	48.1	48.5
31	120.8	40.8	35.7	41.5	78	128.1

Appendix: H-7 Raw Data for pNN50 with RW (%)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	14.1	2.5	2.1	2.6	3.6	3.7
2	25.7	27.6	19.2	14	19.1	22.2
3	37.4	3.3	4	6.3	23.7	7.3
4	46.6	8.1	6.3	5.8	9.3	9.6
5	38	4.8	4.1	7.1	16.2	21.6
6	54.1	10.8	3.6	5.9	9	17.6
7	55.9	17.8	19.9	33.5	48.6	28.3
8	49.5	4.8	4.1	3.1	3.9	4.8
9	15.3	6.2	6.2	8.2	11.3	6.4
10	56.7	6.1	8.6	15.9	10.1	14.5
11	61.7	6.9	6.6	6.2	10.6	12.5
12	7.2	0.9	4.4	2.3	3.3	3
13	72.7	4.4	4.9	2.7	4.7	5.9
14	63.7	2.6	3.4	3.7	4.2	6.1
15	39	5.7	3.6	3.2	5.2	5.2
16	18.2	10.6	5.1	17.8	50.5	51.3
18	47.9	3.2	4.1	9.9	10.6	13.3
19	25.6	3.4	3.4	3.9	3.4	2.4
20	76.3	20.8	38.3	44.9	38.7	38.8
21	56.5	5.3	5.5	6.4	7.3	11.3
22	65	30.9	24.1	25.4	38	42.5
23	48.8	42.3	31.3	31.2	35.6	20.2
24	36	27.2	18.9	21.5	17.1	21.4
25	44.2	12	8.1	11.6	12.7	14.4
26	49.6	22.9	32.5	23.4	25.5	18.9
27	43	15.6	6.9	10.2	5.4	9.7
28	75.7	9.1	3	5.1	7	6.8
29	25.3	21	9.7	11.8	18	16.8
30	20.3	18.6	13.6	18.9	20.9	23.5
31	16.4	7.5	6.6	15.5	20.7	8.9

Appendix: H-8 Raw Data for pNN50 with SW (%)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	13.6	3.1	5.1	5.1	6	6.1
2	36.4	32.2	23.2	12.8	27.6	5.2
3	44.1	12	12.5	18.3	18.2	18.8
4	57.8	7.8	21	19.6	21	20.7
5	51.1	29.7	24.6	20.8	17.1	23.9
6	60.2	4.2	8.3	8.2	11.5	17.9
7	43.7	6.1	9.2	4.8	10.4	14
8	20.2	4.6	4.8	4.8	6.1	7.7
9	10.1	20.6	6.4	11.9	15.3	16.8
10	62	5	3.3	7.8	11.2	20.6
11	19.8	3.8	2.4	5.7	6.6	7.9
12	20.4	0.9	0.7	2	1.5	2.4
13	3.5	3.3	5.4	3.5	3.3	3.6
14	42.6	3.6	6.5	8.7	9.8	12.6
15	26.7	5.3	5.9	10.8	6.3	7.3
16	14.7	16.4	7.7	5.8	19.7	44.7
18	28.2	5.2	1.9	4.3	7.9	7.7
19	18.3	4	4.4	4.1	4	4.1
20	11.6	7	3.1	2.8	3.7	9
21	53	4.8	4.3	5.7	7	6
22	52.4	13.5	16.8	18	21.4	25.8
23	62.2	35.6	42.8	37.1	41.4	40.3
24	33.9	3.6	6.3	5.7	6.3	6.7
25	19.1	5.6	2	6.5	8.6	11.3
26	42.4	25.5	24.5	18.4	22.4	18.3
27	24.9	9.3	7	7.2	13.3	12.8
28	78.2	6.9	4.9	7	14.3	9.2
29	27.1	7.3	4.4	9.9	9.5	9.2
30	32.3	32.6	25.4	24.6	29.3	27.2
31	58	15	15.3	18.1	32.2	55.8

Appendix: H-9 Raw Data for LF power with RW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	506	35	39	31	119	90
2	330	846	420	810	473	1848
3	1232	85	78	370	1069	467
4	1573	166	765	551	466	765
5	1537	364	185	274	974	902
6	2911	467	225	587	967	2128
7	3062	1442	502	859	2801	841
8	1507	55	58	171	227	365
9	389	205	269	834	401	392
10	6050	392	710	1269	708	391
11	14197	203	319	521	623	467
12	539	22	45	56	245	289
13	3565	74	170	85	52	116
14	1303	45	46	223	142	173
15	351	60	21	113	106	240
16	489	820	518	1184	3576	4290
18	1092	194	504	939	802	1414
19	922	118	141	104	367	177
20	988	391	141	222	672	690
21	2557	88	118	174	296	402
22	1033	595	838	785	1153	1272
23	360	380	470	447	330	129
24	638	1179	442	618	427	490
25	1611	425	443	243	547	1047
26	1642	549	1418	1175	1704	1160
27	459	409	292	260	75	121
28	6603	140	103	97	146	118
29	756	293	461	550	1349	566
30	529	673	550	309	785	235
31	531	276	189	464	755	1306

Appendix: H-10 Raw Data for LF power with SW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	710	80	442	570	242	687
2	1760	448	382	82	1317	38
3	413	245	297	1142	715	482
4	1875	137	444	888	910	640
5	3446	768	855	273	212	3140
6	1676	80	304	521	625	655
7	1050	192	631	614	1138	1201
8	755	279	247	332	616	1262
9	1009	534	383	699	1132	2051
10	3919	36	73	98	594	1198
11	2623	88	177	854	1781	438
12	1488	24	9	25	44	48
13	144	18	82	29	81	52
14	1015	111	112	228	353	292
15	412	77	176	78	403	189
16	141	440	891	797	1532	3674
18	1918	190	276	434	735	368
19	324	104	197	365	419	183
20	316	25	21	55	292	317
21	1744	107	263	165	274	244
22	3648	344	1133	2521	1998	1926
23	1669	402	94	62	197	73
24	447	322	449	301	243	218
25	966	171	148	247	331	625
26	1963	576	708	1209	1825	1407
27	1398	20	35	91	329	64
28	4721	62	121	137	424	143
29	839	208	247	242	766	636
30	591	918	1559	1030	922	2162
31	444	396	572	1011	1620	4017

Appendix: H-11 Raw Data for HF power with RW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	596	61	76	73	101	94
2	540	600	401	762	606	1206
3	987	57	60	277	814	204
4	1644	88	109	125	139	220
5	1586	179	84	120	588	808
6	3648	566	155	190	259	597
7	2431	404	324	546	4329	1091
8	1852	84	66	102	94	109
9	418	168	185	318	391	165
10	4189	191	308	554	321	275
11	6383	134	184	203	338	375
12	142	63	54	59	99	78
13	7472	89	87	88	143	171
14	4260	104	69	56	79	123
15	1210	77	70	95	102	119
16	392	184	166	309	1849	1478
18	1290	116	176	253	328	265
19	900	92	63	60	53	63
20	10050	843	449	398	596	969
21	2344	89	190	236	202	465
22	2532	999	643	578	1008	1655
23	1625	1186	669	1012	1045	506
24	1088	548	666	420	473	508
25	1416	447	171	333	359	461
26	1413	650	1062	804	584	421
27	1974	465	363	222	218	280
28	10274	157	51	127	113	213
29	626	206	333	285	438	489
30	613	489	377	419	662	638
31	324	170	115	213	294	479

Appendix: H-12 Raw Data for HF power with SW (ms)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	299	87	137	141	161	172
2	788	1252	1236	766	2350	156
3	911	253	231	176	648	312
4	1298	121	306	376	424	381
5	5754	1319	847	535	423	855
6	4777	182	344	356	385	398
7	887	137	175	176	239	279
8	640	89	106	154	96	149
9	215	413	195	293	299	466
10	4955	86	82	142	196	376
11	636	69	91	132	262	143
12	696	41	43	51	52	56
13	105	64	68	66	94	106
14	2565	126	164	209	193	305
15	700	119	110	128	190	216
16	474	543	153	146	634	2413
18	524	114	87	102	198	167
19	582	97	131	95	117	166
20	515	161	66	90	115	117
21	2751	76	87	109	179	108
22	2089	596	405	1007	723	588
23	2463	796	630	697	886	924
24	895	132	270	282	307	291
25	564	99	84	135	182	282
26	959	638	761	455	560	640
27	729	289	229	238	378	394
28	17939	103	126	146	269	138
29	917	177	123	508	217	406
30	938	693	642	650	675	533
31	3823	233	281	568	2249	5655

Appendix: H-13 Raw Data for LF power with RW (n.u.)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	42.8	33.2	33.9	31	54.2	46.2
2	37.9	53.3	51.2	810	43.8	58.2
3	55.5	60.1	55.7	370	56.8	69.6
4	48.9	65.4	87.5	551	77	77.7
5	44.3	67.1	68.7	274	62.3	52.8
6	44.4	45.2	59.1	587	78.9	78.1
7	55.7	78.1	60.7	859	39.3	43.5
8	44.9	39.7	46.6	171	70.7	76.9
9	48.2	55	59.3	834	50.6	70.3
10	59.1	67.2	69.7	1269	68.8	58.7
11	69	60.3	63.3	521	64.9	55.5
12	79.1	25.8	45.2	56	71.2	78.7
13	32.3	45.5	66.1	85	26.5	40.4
14	23.4	30	40.3	223	64.4	58.4
15	22.5	43.9	23.6	113	51.1	67
16	55.5	81.7	75.7	1184	65.9	74.4
18	45.8	62.7	74.2	939	71	83.6
19	50.6	56.3	69.3	104	87.3	73.7
20	8.9	31.7	23.8	222	53	41.6
21	52.2	49.7	38.4	174	59.5	46.4
22	29	37.3	56.6	785	53.4	43.5
23	18.2	24.3	41.2	447	24	20.3
24	37	68.2	39.9	618	47.4	49.1
25	53.2	48.7	72.1	243	60.4	69.5
26	53.7	45.8	57.2	1175	74.5	73.4
27	12.7	46.8	44.6	260	25.5	30.2
28	39.1	47.1	66.7	97	56.4	35.6
29	54.7	58.7	58	550	75.5	53.6
30	46.3	57.9	59.4	309	54.2	26.9
31	62.1	61.9	62.3	464	72	73.2

Appendix: H-14 Raw Data for LF power with SW (n.u.)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	65.3	47.8	76.3	80.1	60.1	79.9
2	69.1	26.4	23.6	9.6	35.9	19.5
3	31.2	49.2	56.2	86.7	52.5	60.7
4	59.1	53.1	59.1	70.3	68.2	62.7
5	40.7	36.8	50.2	33.8	33.4	78.6
6	26	30.5	46.9	59.4	61.9	62.2
7	54.2	58.3	78.3	77.8	82.7	81.2
8	54.1	75.8	69.9	68.3	86.5	89.4
9	82.5	56.4	66.3	70.4	79.1	81.5
10	44.2	29.3	47	40.8	75.2	76.1
11	80.5	56.2	66.2	86.6	87.2	75.3
12	68.1	36.5	17	32.6	45.6	46.1
13	57.9	21.7	54.9	30.3	46.4	32.7
14	28.4	46.8	40.7	52.3	64.6	49
15	37	39.3	61.5	37.7	68	46.5
16	22.9	44.8	85.3	84.5	70.7	60.4
18	78.5	62.5	76	81	78.8	68.8
19	35.7	51.7	60	79.4	78.2	52.5
20	38	13.6	24.4	37.7	71.7	73.1
21	38.8	58.4	75.3	60.2	60.5	69.4
22	63.6	36.6	73.7	71.4	73.4	76.6
23	40.4	33.5	13	8.2	18.2	7.3
24	33.3	70.9	62.5	51.7	44.2	42.8
25	58.1	63.3	63.7	64.8	64.4	68.9
26	67.2	47.5	48.2	72.6	76.5	68.7
27	65.7	6.5	13.1	27.7	46.6	13.9
28	23.4	37.4	49	48.3	61.2	50.9
29	47.8	53.9	66.7	32.3	78	61
30	38.6	57	70.8	61.3	57.7	80.2
31	10.4	63	67.1	64	41.9	41.5

Appendix: H-15 Raw Data for HF power with RW (n.u.)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	50.4	58.5	66.1	67.5	45.8	47.9
2	62.1	37.8	48.8	47.5	56.2	38
3	44.5	39.9	44.3	42.8	43.2	30.4
4	51.1	34.6	12.5	18.5	23	22.3
5	55.7	32.9	31.3	30.4	37.7	47.2
6	55.6	54.8	40.9	24.4	21.1	21.9
7	44.3	21.9	39.3	38.8	60.7	56.5
8	55.1	60.3	53.4	37.5	29.3	23.1
9	51.8	45	40.7	27.6	49.4	29.7
10	40.9	32.8	30.3	30.4	31.2	41.3
11	31	39.7	36.7	28	35.1	44.5
12	20.9	74.2	54.8	51.7	28.8	21.3
13	67.7	54.5	33.9	50.9	73.5	59.6
14	76.6	70	59.7	20.2	35.6	41.6
15	77.5	56.1	76.4	45.8	48.9	33
16	45.5	18.3	24.3	20.7	34.1	25.6
18	54.2	37.3	25.8	21.2	29	16.4
19	49.4	43.7	30.7	36.5	12.7	26.3
20	91.1	68.3	76.2	64.2	47	58.4
21	47.8	50.3	61.6	57.5	40.5	53.6
22	71	62.7	43.4	42.4	46.6	56.5
23	81.8	75.7	58.8	69.3	76	79.7
24	63	31.8	60.1	40.4	52.6	50.9
25	46.8	51.3	27.9	57.8	39.6	30.5
26	46.3	54.2	42.8	40.6	25.5	26.6
27	87.3	53.2	55.4	46.1	74.5	69.8
28	60.9	52.9	33.3	56.7	43.6	64.4
29	45.3	41.3	42	34.1	24.5	46.4
30	53.7	42.1	40.6	57.5	45.8	73.1
31	37.9	38.1	37.7	31.5	28	26.8

Appendix: H-16 Raw Data for HF power with SW (n.u.)

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	27.6	52.2	23.7	19.9	39.9	20.1
2	30.9	73.6	76.4	90.4	64.1	80.5
3	68.8	50.8	43.8	13.3	47.5	39.3
4	40.9	46.9	40.9	29.7	31.8	37.3
5	59.3	63.2	49.8	66.2	66.6	21.4
6	74	69.5	53.1	40.6	38.1	37.8
7	45.8	41.7	21.7	22.2	17.3	18.8
8	45.9	24.2	30.1	31.7	13.5	10.6
9	17.5	43.6	33.7	29.6	20.9	18.5
10	55.8	70.7	53	59.2	24.8	23.9
11	19.5	43.8	33.8	13.4	12.8	24.7
12	31.9	63.5	83	67.4	54.4	53.9
13	42.1	78.3	45.1	69.7	53.6	67.3
14	71.6	53.2	59.3	47.7	35.4	51
15	63	60.7	38.5	62.3	32	53.5
16	77.1	55.2	14.7	15.5	29.3	39.6
18	21.5	37.5	24	19	21.2	31.2
19	64.3	48.3	40	20.6	21.8	47.5
20	62	86.4	75.6	62.3	28.3	26.9
21	61.2	41.6	24.7	39.8	39.5	30.6
22	36.4	63.4	26.3	28.6	26.6	23.4
23	59.6	66.5	87	91.8	81.8	92.7
24	66.7	29.1	37.5	48.3	55.8	57.2
25	36.9	36.7	36.3	35.2	35.6	31.1
26	32.8	52.5	51.8	27.4	23.5	31.3
27	34.3	93.5	86.9	72.3	53.4	86.1
28	76.6	62.6	51	51.7	38.8	49.1
29	52.2	46.1	33.3	67.7	22	39
30	61.4	43	29.2	38.7	42.3	19.8
31	89.6	37	32.9	36	58.1	58.5

Appendix: H-17 Raw Data for LF/HF power with RW

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	0.8	0.6	0.5	0.4	1.2	1
2	0.6	1.4	1	1.1	0.8	1.5
3	1.2	1.5	1.3	1.3	1.3	2.3
4	1	1.9	7	4.4	3.3	3.5
5	0.8	2	2.2	2.3	1.7	1.1
6	0.8	0.8	1.4	3.1	3.7	3.6
7	1.3	3.6	1.5	1.6	0.6	0.8
8	0.8	0.7	0.9	1.7	2.4	3.3
9	0.9	1.2	1.5	2.6	1	2.4
10	1.4	2.1	2.3	2.3	2.2	1.4
11	2.2	1.5	1.7	2.6	1.8	1.2
12	3.8	0.3	0.8	0.9	2.5	3.7
13	0.5	0.8	1.9	1	0.4	0.7
14	0.3	0.4	0.7	3.9	1.8	1.4
15	0.3	0.8	0.3	1.2	1	2
16	1.2	4.5	3.1	3.8	1.9	2.9
18	0.8	1.7	2.9	3.7	2.4	5.1
19	1	1.3	2.3	1.7	6.865	2.8
20	0.1	0.5	0.3	0.6	1.1	0.7
21	1.1	1	0.6	0.7	1.5	0.9
22	0.4	0.6	1.3	1.4	1.1	0.8
23	0.2	0.3	0.7	0.4	0.3	0.3
24	0.6	2.1	0.7	1.5	0.9	1
25	1.1	1	2.6	0.7	1.5	2.3
26	1.2	0.8	1.3	1.5	2.9	2.8
27	0.1	0.9	0.8	1.2	0.3	0.4
28	0.6	0.9	2	0.8	1.3	0.6
29	1.2	1.4	1.4	1.9	3.1	1.2
30	0.9	1.4	1.5	0.7	1.2	0.4
31	1.6	1.6	1.6	2.2	2.6	2.7

Appendix: H-18 Raw Data for LF/HF power with SW

Subject ID	Baseline	5 min-post	10 min-post	15 min-post	20 min-post	25 min-post
1	2.4	0.9	3.2	4	1.5	4
2	2.2	0.4	0.3	0.1	0.6	0.2
3	0.5	1	1.3	6.5	1.1	1.5
4	1.4	1.1	1.4	2.4	2.1	1.7
5	0.7	0.6	1	0.5	0.5	3.7
6	0.4	0.4	0.9	1.5	1.6	1.6
7	1.2	1.4	3.6	3.5	4.8	4.3
8	1.2	3.1	2.3	2.2	6.4	8.5
9	4.7	1.3	2	2.4	3.8	4.4
10	0.8	0.4	0.9	0.7	3	3.2
11	4.1	1.3	2	6.5	6.8	3.1
12	2.1	0.6	0.2	0.5	0.8	0.9
13	1.4	0.3	1.2	0.4	0.9	0.5
14	0.4	0.9	0.7	1.1	1.8	1
15	0.6	0.6	1.6	0.6	2.1	0.9
16	0.3	0.8	5.8	5.5	2.4	1.5
18	3.7	1.7	3.2	4.3	3.7	2.2
19	0.6	1.1	1.5	3.9	3.6	1.1
20	0.6	0.2	0.3	0.6	2.5	2.7
21	0.6	1.4	3	1.5	1.5	2.3
22	1.7	0.6	2.8	2.5	2.8	3.3
23	0.7	0.5	0.1	0.1	0.2	0.1
24	0.5	2.4	1.7	1.1	0.8	0.7
25	1.7	1.7	1.8	1.8	1.8	2.2
26	2	0.9	0.9	2.7	3.3	2.2
27	1.9	0.1	0.2	0.4	0.9	0.2
28	0.3	0.6	1	0.9	1.6	1
29	0.9	1.2	2	0.5	3.5	1.6
30	0.6	1.3	2.4	1.6	1.4	4.1
31	0.1	1.7	2	1.8	0.7	0.7

APPENDIX I:
Raw Data for HR

Appendix: I-1 Raw Data for HR with RW

ID #	Baseline	Peak	5min-post	10min-post	15min-post	20min-post	25min-post	30min-post
1	85	163	101	94	94	91	88	89
2	57	155	70	69	64	68	63	62
3	62	174	95	95	90	87	83	79
4	64	164	91	88	93	80	81	78
5	60	178	85	97	87	75	70	69
6	65	167	89	97	85	79	76	82
7	58	179	70	70	70	67	62	65
8	60	167	91	92	90	85	87	88
9	67	147	78	77	70	69	71	74
10	54	162	93	87	85	78	74	81
11	50	161	87	76	68	65	64	62
12	85	174	114	107	104	102	101	92
13	61	163	94	92	89	89	85	85
14	67	170	102	103	104	99	96	91
15	52	159	92	92	90	84	82	77
16	44	169	76	85	86	56	57	60
18	49	155	74	78	79	73	67	62
19	80	176	106	102	110	103	98	101
20	64	185	98	94	97	89	88	82
21	54	177	99	97	96	92	91	83
22	58	148	77	71	72	70	62	58
23	48	178	64	67	63	63	63	64
24	52	151	65	62	57	59	65	60
25	51	166	80	79	74	74	66	65
26	53	154	75	77	71	70	71	68
27	57	155	71	76	78	75	74	71
28	56	164	91	92	95	87	88	82
29	63	166	87	81	79	75	73	74
30	71	156	72	72	77	70	74	68
31	57	174	102	94	95	84	87	81

Appendix: I-2 Raw Data for HR with SW

ID #	Baseline	Peak	5min-post	10min-post	15min-post	20min-post	25min-post	30min-post
1	70	152	95	90	90	83	79	78
2	59	156	74	73	69	68	66	61
3	58	164	89	86	76	72	78	72
4	57	155	82	84	71	64	74	68
5	59	145	66	64	67	67	65	58
6	68	173	95	94	87	77	77	73
7	52	174	78	77	73	71	67	69
8	67	164	88	90	88	87	80	80
9	63	156	80	77	75	75	67	65
10	58	165	94	91	88	83	86	82
11	67	171	98	91	8	76	75	73
12	73	174	116	119	117	111	103	95
13	92	167	105	109	106	97	96	92
14	75	165	99	102	96	90	89	87
15	56	158	83	86	88	79	70	72
16	50	170	86	83	81	79	68	60
18	55	164	74	79	99	77	70	67
19	81	167	92	94	86	101	92	89
20	81	174	98	101	96	93	90	85
21	49	186	103	100	91	106	108	99
22	66	153	93	85	81	79	71	75
23	52	177	59	62	62	60	61	60
24	52	161	77	77	70	67	64	64
25	72	158	108	88	95	86	89	75
26	57	145	80	74	72	66	65	62
27	59	151	76	76	75	71	70	65
28	57	167	89	88	87	89	75	83
29	66	176	95	89	92	85	78	83
30	64	155	69	66	65	66	64	65
31	63	165	70	75	87	83	77	79

Appendix J:
Raw Data for PRS Scores

Appendix: J-1 Raw Data for PRS with RW

ID #	5min-post	10min-post	15min-post	20min-post	25min-post	30min-post
1	4	5	5	6	6	7
2	4	4	6	7	8	8
3	7	8	9	10	10	10
4	4	5	7	8	8	8
5	4	6	8	8	10	10
6	4	5	5	5	6	7
7	5	6	8	8	8	8
8	2	4	5	6	6	6
9	2	5	7	8	9	9
10	5	6	7	8	8	8
11	4	8	9	9	10	10
12	3	4	5	6	8	8
13	2	4	5	5	6	6
14	2	5	7	9	9	10
15	3	5	6	8	8	9
16	4	7	8	8	8	8
18	10	10	10	10	10	10
19	5	8	8	8	9	9
20	2	3	5	5	5	6
21	6	7	8	8	9	9
22	7	8	10	10	10	10
23	5	6	8	8	9	9
24	8	8	8	9	9	9
25	6	7	8	9	10	10
26	5	7	8	9	9	9
27	8	10	10	10	10	10
28	7	7	9	9	9	9
29	3	5	6	7	7	8
30	6	7	7	8	8	8
31	7	9	10	10	10	10

Appendix: J-2 Raw Data for PRS with SW

ID #	5min-post	10min-post	15min-post	20min-post	25min-post	30min-post
1	3	3	5	6	7	8
2	4	6	6	8	8	9
3	5	7	8	9	9	10
4	5	7	8	8	9	9
5	2	6	8	10	10	10
6	4	5	6	7	7	7
7	4	6	7	8	8	8
8	2	4	6	6	8	8
9	2	4	6	8	9	9
10	4	5	5	6	7	7
11	4	4	4	4	4	5
12	2	3	4	6	7	7
13	3	4	5	5	5	5
14	4	7	8	9	9	10
15	6	7	8	8	9	9
16	3	4	7	7	7	7
18	8	10	10	10	10	10
19	6	6	7	7	8	8
20	5	7	7	8	8	8
21	4	6	7	8	8	9
22	6	6	7	7	7	7
23	3	5	7	8	9	9
24	6	7	7	8	8	8
25	6	8	9	10	10	10
26	6	8	10	10	10	10
27	7	10	10	10	10	10
28	4	4	5	6	6	8
29	3	5	5	6	7	8
30	5	6	6	7	8	8
31	7	9	10	10	10	10

APPENDIX K:
Raw Data for WAnTs

Appendix: K-1 WAnTs Corrected Mean and Corrected Peak (W) (RW)

ID #	Corrected Mean WAnT1	Corrected Mean WAnT2	Corrected Peak WAnT1	Corrected Peak WAnT2
1	539	560	748	761
2	396.8	408.8	459.1	473.2
3	582.6	515.4	792.3	676.8
4	444	463.6	517.7	558
5	758.7	718.5	931.9	901.7
6	492	480.6	623.1	589.2
7	377.2	392.6	460.4	454.9
8	411.6	442.4	517.6	568
9	357.9	325.9	460.2	397.3
10	375.6	387.1	481.1	477.6
11	656.3	634.3	775.8	792.2
12	527.6	524.5	638.4	594
13	386.2	393.8	452.3	478.9
14	378.2	366.6	486.2	444.8
15	688.3	771.3	914	1006
16	644.8	694.4	800.3	839.2
18	614	586.9	679.4	654
19	470.4	439.9	629.1	625.1
20	301.1	324.7	399.1	398.2
21	620.9	614.5	747.7	737.1
22	553.2	601.3	705.5	680.1
23	327.9	328.8	400.9	410.3
24	470.3	476.5	599.2	569.7
25	345.6	367.7	421.3	424.5
26	794	853.8	951.2	940.4
27	283.1	266	365.3	306.7
28	472.2	456.5	621.5	533.2
29	446	399.8	540.7	491.5
30	240.2	207.5	325.7	287.7
31	702.2	733	863.1	858.6

Appendix: K-2 WAnTs Corrected Mean and Corrected Peak (W) (SW)

ID #	Corrected Mean WAnT1	Corrected Mean WAnT2	Corrected Peak WAnT1	Corrected Peak WAnT2
1	476.9	511.5	574.7	569.3
2	372.8	374.4	428.9	419.7
3	551.8	573.2	720.3	731.2
4	472.4	390.6	557.7	479.2
5	704.6	719.3	851.5	806.7
6	450.9	469.6	599	571.5
7	420.9	433.9	486.6	488.2
8	331.2	394.8	502	512.4
9	357.1	365.3	431.8	441.5
10	407.6	437.9	497.2	504.5
11	697.7	683.5	863.7	798.4
12	525.1	500.3	660.6	619.1
13	405.5	390.2	541.8	470.4
14	366.6	358.1	478.1	439.4
15	738.1	763.1	944	915.3
16	708.2	710.3	845.4	867.1
18	652.7	613	710.2	703.7
19	426.4	475.1	642.4	610
20	357.5	324.1	441.1	391.7
21	605.9	641.9	738.7	790.8
22	5833	575.2	687.7	626.5
23	333.2	324.8	397.9	394.9
24	567	538.8	669.1	617.2
25	347.9	330.8	436.8	429.5
26	709.5	745.7	791.1	851.5
27	242.5	265.2	320.6	321.7
28	488.4	484.6	603.9	596.4
29	402.1	431.7	490	537.4
30	253.2	260	320.2	320.4
31	651.2	641.1	761.3	746.8

Appendix: K-3 WAnTs Corrected Minimum (W) and % Decrease (RW)

ID #	Corrected Min WAnT1	Corrected Min WAnT2	% Decrease WAnT1	% Decrease WAnT2
1	406	446	45.8	41.4
2	322.4	289.1	29.8	38.9
3	401.5	387.8	49.3	42.7
4	377.8	402.1	27	27.9
5	618.7	532.8	33.6	40.9
6	388.6	384.3	37.6	34.8
7	193	326.6	58.1	28.2
8	292.3	286.2	43.5	49.6
9	254.8	227.9	44.6	42.6
10	273.1	288.8	43.2	39.5
11	517.1	544.1	33.3	31.3
12	449.2	440.3	29.6	25.9
13	324.1	322.9	28.3	32.6
14	298.4	301	38.6	32.3
15	537.8	570.9	41.2	43.3
16	485.5	535.6	39.3	36.2
18	555.4	503.3	18.3	23
19	347.2	352.5	44.8	43.6
20	137.7	257.7	65.5	35.3
21	467.8	502.9	37.4	31.8
22	423.6	516.5	40	24.1
23	267.8	259.8	33.2	36.7
24	373.1	373.8	37.7	34.4
25	285.2	282.3	32.3	33.5
26	652.3	746.6	31.4	20.6
27	223.2	217.2	38.9	29.2
28	242.5	361.5	61	32.2
29	372.8	339.5	31.1	30.9
30	153.7	158.1	52.8	45
31	555.3	588.5	35.7	31.5

Appendix: K-4 WAnTs Corrected Minimum (W) and % Decrease (SW)

ID #	Corrected Min WAnT1	Corrected Min WAnT2	% Decrease WAnT1	% Decrease WAnT2
1	364.6	362.7	36.6	36.3
2	303.9	278.9	29.1	33.5
3	363.4	435.1	49.5	40.5
4	366	274.9	34.4	42.6
5	591.5	637.9	30.5	20.9
6	320.6	409.8	46.5	28.3
7	328.8	331.3	32.4	32.1
8	191.3	167.5	61.9	67.3
9	283	270.4	34.5	38.7
10	336	381.8	32.4	24.3
11	567.3	490.9	34.3	38.5
12	399.1	387.2	39.6	37.5
13	157	326.5	71	30.6
14	295	283.7	38.3	35.4
15	584.8	652.5	38	28.7
16	585.4	561.3	30.7	35.3
18	582.2	390.3	18	44.5
19	-11.9	362.3	101.9	40.6
20	233.1	257.2	47.2	34.3
21	482.6	485	34.7	38.7
22	458.7	518.5	33.3	17.2
23	271.5	218.3	31.8	44.7
24	435.7	456.9	34.9	26
25	248.7	254.3	43.1	40.8
26	601	615.8	24	27.7
27	160.6	224.7	49.9	30.2
28	384.9	393.3	36.3	34
29	290.5	318.3	40.7	40.8
30	171.8	181.2	46.4	43.4
31	541	540.2	28.9	27.7

REFERENCES

1. Halson SL, Bridge MW, Meeusen R, et al. Time course of performance changes and fatigue markers during intensified training in trained cyclists. *J Appl Physiol.* Sep 2002;93(3):947-956.
2. Allen DG, Lamb GD, Westerblad H. Skeletal muscle fatigue: cellular mechanisms. *Physiol Rev.* Jan 2008;88(1):287-332.
3. Juel C. Muscle pH regulation: role of training. *Acta Physiol Scand.* Mar 1998;162(3):359-366.
4. Richardson RS, Noyszewski EA, Leigh JS, Wagner PD. Lactate efflux from exercising human skeletal muscle: role of intracellular PO2. *J Appl Physiol.* Aug 1998;85(2):627-634.
5. Del Coso J, Hamouti N, Aguado-Jimenez R, Mora-Rodriguez R. Restoration of blood pH between repeated bouts of high-intensity exercise: effects of various active-recovery protocols. *Eur J Appl Physiol.* Feb 2010;108(3):523-532.
6. Katch VL, Gilliam T, Weltman A. Active vs. passive recovery from short-term supramaximal exercise. *Res Q.* May 1978;49(2):153-161.
7. Menzies P, Menzies C, McIntyre L, Paterson P, Wilson J, Kemi OJ. Blood lactate clearance during active recovery after an intense running bout depends on the intensity of the active recovery. *J Sports Sci.* 2010;28(9):975-982.
8. Ahmaidi S, Granier P, Taoutaou Z, Mercier J, Dubouchaud H, Prefaut C. Effects of active recovery on plasma lactate and anaerobic power following repeated intensive exercise. *Med Sci Sports Exerc.* Apr 1996;28(4):450-456.
9. Bishop D, Ruch N, Paun V. Effects of active versus passive recovery on thermoregulatory strain and performance in intermittent-sprint exercise. *Med Sci Sports Exerc.* May 2007;39(5):872-879.
10. Dupont G, Moalla W, Matran R, Berthoin S. Effect of short recovery intensities on the performance during two Wingate tests. *Med Sci Sports Exerc.* Jul 2007;39(7):1170-1176.
11. Gupta S, Goswami A, Sadhukhan AK, Mathur DN. Comparative study of lactate removal in short term massage of extremities, active recovery and a passive recovery period after supramaximal exercise sessions. *Int J Sports Med.* Feb 1996;17(2):106-110.
12. Sairyo K, Iwanaga K, Yoshida N, et al. Effects of active recovery under a decreasing work load following intense muscular exercise on intramuscular energy metabolism. *Int J Sports Med.* Apr 2003;24(3):179-182.
13. Siegler JC, Bell-Wilson J, Mermier C, Faria E, Robergs RA. Active and passive recovery and acid-base kinetics following multiple bouts of intense exercise to exhaustion. *Int J Sport Nutr Exerc Metab.* Feb 2006;16(1):92-107.
14. Spierer DK, Goldsmith R, Baran DA, Hryniewicz K, Katz SD. Effects of active vs. passive recovery on work performed during serial supramaximal exercise tests. *Int J Sports Med.* Feb 2004;25(2):109-114.

15. Chatard JC, Atlaoui D, Farjanel J, Louisy F, Rastel D, Guezennec CY. Elastic stockings, performance and leg pain recovery in 63-year-old sportsmen. *Eur J Appl Physiol.* Dec 2004;93(3):347-352.
16. Duffield R, Cannon J, King M. The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise. *J Sci Med Sport.* Jan 2010;13(1):136-140.
17. Gill ND, Beaven CM, Cook C. Effectiveness of post-match recovery strategies in rugby players. *Brit J Sport Med.* Mar 2006;40(3):260-263.
18. Burnett A. Using recovery modalities between training sessionsin elite athletes. Does it help? *Sports Med.* 2006;36:781-796.
19. Borresen J, Lambert MI. Autonomic control of heart rate during and after exercise : measurements and implications for monitoring training status. *Sports Med.* 2008;38(8):633-646.
20. Heffernan KS, Fahs CA, Shinsako KK, Jae SY, Fernhall B. Heart rate recovery and heart rate complexity following resistance exercise training and detraining in young men. *Am J Physiol Heart Circ Physiol.* Nov 2007;293(5):H3180-3186.
21. Javorka M, Zila I, Balharek T, Javorka K. Heart rate recovery after exercise: relations to heart rate variability and complexity. *Braz J Med Biol Res.* Aug 2002;35(8):991-1000.
22. Nunan D, Jakovljevic DG, Donovan G, Singleton LD, Sandercock GR, Brodie DA. Resting autonomic modulations and the heart rate response to exercise. *Clin Auton Res.* Aug 2010;20(4):213-221.
23. Raczak G, Pinna GD, La Rovere MT, et al. Cardiovagal response to acute mild exercise in young healthy subjects. *Circ J.* Aug 2005;69(8):976-980.
24. Ghoneum M, Ghoneum A, Gimzewski J. Nanodiamond and nanoplatinum liquid, DPV576, activates human monocyte-derived dendritic cells in vitro. *Anticancer Res.* Oct 2010;30(10):4075-4079.
25. Ghoneum M, Ghoneum A, Tolentino L, Gimzewski J. Modulation of aged murine T lymphocytes in vivo by DPV576-C, a nanodiamond- and nanoplatinum-coated material. *In Vivo.* Mar-Apr 2010;24(2):141-146.
26. Katano H, Matsui H, Ohba M, Tsukiji M. Effect of Stress Reduction of Bed Padding Made of Hybrid (DPV576-F) Material Pad using Nano Platinum and Nano Diamond. *Med Biol.* 2010;154(2):86-91.
27. Stickley CD, Hetzler RK, Kimura IF. Prediction of anaerobic power values from an abbreviated WAnT protocol. *J Strength Cond Res.* May 2008;22(3):958-965.
28. Laurent CM, Green JM, Bishop PA, et al. A practical approach to monitoring recovery: development of a perceived recovery status scale. *J Strength Cond Res.* Mar 2011;25(3):620-628.
29. Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med.* 1970;2:92-98.
30. Kannankeril PJ, Le FK, Kadish AH, Goldberger JJ. Parasympathetic effects on heart rate recovery after exercise. *J Investig Med.* Sep 2004;52(6):394-401.
31. Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Task Force of the European Society of

Cardiology and the North American Society of Pacing and Electrophysiology. *Eur Heart J.* Mar 1996;17(3):354-381.

32. **Goldberger JJ, Le FK, Lahiri M, Kannankeril PJ, Ng J, Kadish AH. Assessment of parasympathetic reactivation after exercise. *Am J Physiol Heart Circ Physiol.* Jun 2006;290(6):H2446-2452.**
33. **Pierpont GL, Stolpman DR, Gornick CC. Heart rate recovery post-exercise as an index of parasympathetic activity. *J Auton Nerv Syst.* May 12 2000;80(3):169-174.**
34. **Buchheit M, Laursen PB, Ahmaidi S. Parasympathetic reactivation after repeated sprint exercise. *Am J Physiol Heart Circ Physiol.* Jul 2007;293(1):H133-141.**
35. **Gladwell VF, Sandercock GR, Birch SL. Cardiac vagal activity following three intensities of exercise in humans. *Clin Physiol Funct Imaging.* Jan 2010;30(1):17-22.**
36. **Casonatto J, Tinucci T, Dourado AC, Polito M. Cardiovascular and autonomic responses after exercise sessions with different intensities and durations. *Clinics (Sao Paulo).* 2011;66(3):453-458.**
37. **Takahashi T, Okada A, Saitoh T, Hayano J, Miyamoto Y. Difference in human cardiovascular response between upright and supine recovery from upright cycle exercise. *Eur J Appl Physiol.* Feb 2000;81(3):233-239.**
38. **Yamamoto K, Miyachi M, Saitoh T, Yoshioka A, Onodera S. Effects of endurance training on resting and post-exercise cardiac autonomic control. *Med Sci Sports Exerc.* Sep 2001;33(9):1496-1502.**
39. **Gellish RL, Goslin BR, Olson RE, McDonald A, Russi GD, Moudgil VK. Longitudinal modeling of the relationship between age and maximal heart rate. *Med Sci Sports Exerc.* May 2007;39(5):822-829.**
40. **Cleary MA, Hetzler RK, Wages JJ, Lentz MA, Stickley CD, Kimura IF. Comparisons of age-predicted maximum heart rate equations in college-aged subjects. *J Strength Cond Res.* Sep 2011;25(9):2591-2597.**
41. **Bangsbo J, Madsen K, Kiens B, Richter EA. Muscle glycogen synthesis in recovery from intense exercise in humans. *Am J Physiol.* Aug 1997;273(2 Pt 1):E416-424.**
42. **Martin NA, Zoeller RF, Robertson RJ, Lephart SM. The comparative effects of sports massage, active recovery, and rest in promoting blood lactate clearance after supramaximal leg exercise. *J Athl Train.* Jan 1998;33(1):30-35.**
43. **Monedero J, Donne B. Effect of recovery interventions on lactate removal and subsequent performance. *Int J Sports Med.* Nov 2000;21(8):593-597.**
44. **Philp A, Macdonald AL, Watt PW. Lactate--a signal coordinating cell and systemic function. *J Exp Biol.* Dec 2005;208(Pt 24):4561-4575.**
45. **Wigernaes I, Hostmark AT, Stromme SB, Kierulf P, Birkeland K. Active recovery and post-exercise white blood cell count, free fatty acids, and hormones in endurance athletes. *Eur J Appl Physiol.* Apr 2001;84(4):358-366.**
46. **Rowell LB, O'Leary DS. Reflex control of the circulation during exercise: chemoreflexes and mechanoreflexes. *J Appl Physiol.* Aug 1990;69(2):407-418.**