【Original paper】

The Effects of DPV576 Nanodiamond and Nanoplatinum Coated Recovery Garments on Heart Rate Variability Following the Wingate Anaerobic Test

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ABSTRACT

This study examined the effect of DPV576-coated recovery garments following a High-Intensity anaerobic exercise on Heart Rate Recovery (HRR) and Heart Rate Variability (HRV). Thirty young adults (15 males: 23.7±4.1 yrs; 15 females: 23.2±3.0 yrs) performed a modified Wingate Anaerobic Test (mWAnT, 20 seconds) followed by a 20-minute supine rest, during which RR intervals were collected in five-minute intervals and used to assess time- and frequency-domain measures of HRV. The Perceived Recovery Status (PRS) was also collected every five-minutes during recovery. A subsequent mWAnT was then performed. This was performed once using DPV576 Nanodiamond and Nanoplatinum Coated Recovery Garments and once using sham garments. There were no significant differences between garments in measures of HRR (p=0.401 or higher), HRV (p=0.158 or higher) or Wingate peak power (Initial mWAnT 610.3±179.8 vs 599.8±167.1, p=0.885, subsequent mWAnT 597.7±189.0 vs. 585.7±167.9, p=0.885). While the PRS scores were consistently higher with the experimental garment, these differences were not significant. However, there was a significant difference in the linear trend of the low-frequency to high-frequency ratio in frequency domain measures of HRV (p<0.05). DPV576 coated garment had no immediate effect on HRR, HRV, and PRS during recovery following performance of high-intensity anaerobic exercise. There are no practical benefits in terms of HRR or HRV for used of DPV576-coated recovery garments for short-term (30 minutes) recovery between intense anaerobic exercise bouts.

KEY WORDS: HRV, Recovery, HRR, Autonomic, WAnT

I. Introduction

Rapid recovery from repeated bouts of high intensity exercises within short periods of time should be beneficial for athletes to enhance subsequent performance and prevent chronic overtraining[23]. Both active and passive recovery protocols have been employed to enhance the return to homeostasis after the exercise. Numerous studies have shown that active recovery, via continuously engaging exercise at low intensity, is the most effective method to decrease blood lactate levels[1, 12, 22, 31, 32]. However, active recovery is not always feasible[12]. Active recovery increases blood circulations through involvement of the "muscle pump" and vasodilation, which facilitates the lactate buffering capacity and oxygen delivery to the muscle. Active recovery will also increase the metabolism of lactate by recruiting type I muscle fibers, re-converting lactate to pyruvate in muscle and to glucose in the liver during the recovery period[22, 31, 32].

Passive (resting) recovery has also been investigated utilizing compression garments both during exercise and the post-exercise recovery period. Research involving theses garments are inconclusive[9, 11, 19] and have revealed little effect on recovery[7]. However, a recent meta-analysis by Hill et al.[24] suggested that there was a moderate effect size for compression garments to enhance recovery from

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exercise protocols designed to induce muscle damage. Pooled data indicated that the use of compression garments had a moderate effect (Hedges' *g* ranging from *g*=0.403 to 0.487) in reducing: the severity of delayed onset muscle soreness, the loss of muscle strength and power, and blood levels of creatine kinase[24]. They concluded that compression garments are effective in enhancing recovery by reducing muscle damage[24]. Additionally Beliard et al.[2] recently reported that wearing compression garments (regardless of the amount of pressure) during recovery seems to be beneficial for performance recovery.

Specific warm-up, warm-down, or compression garments have been developed to promote quicker recovery via choice of materials or fabrics. Recently, mixtures of nano-platinum and nano-diamond coated materials (DPV576) have been applied to recovery-specific garments. A previous study reported that mice living in a mouse house lined with DPV576-C displayed an increase in $CD4^+$ and $CD8^+$ T-cells, suggesting that this material may be useful for patients suffering from immune dysfunction[17]. The same laboratory also found that the DPV576 activated human dendric cells and DC-driven CD4 naïve T-cell proliferation in vitro, which may be beneficial in increasing immune system in cancer treatment[16]; and that DPV576 is an effective chemo-sensitizer for the treatment of chemo-resistant human myeloid leukemia[15]. Most recently, it has been shown that DPV576 activates human keratinocytes, which may reduce stress associated with inflammation, pain and circadian rhythms[18].

Katano et al. (2010) reported that bed padding made of DPV576-F materials effectively reduced chromogranin-A concentration in saliva in healthy adults after being subjected to a mental stress (five-minute math test)[27]. The Venex Co., Ltd. (Kanagawa, Japan) produced a garment utilizing DPV576 specifically designed to augment recovery from exercise via stimulation of the parasympathetic nervous system, whereby heart rate recovery (HRR) is enhanced[4]. A reduction in stress should result in changes in the autonomic nervous function, which may be determined by assessing Heart Rate Variability (HRV).

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 anaerobic exercise. Therefore, the purpose of this study was to investigate the effect DPV576 coated recovery garments after a high intensity exercise bout on the HRR and parasympathetic tone via HRV. Specifically, subjects completed a modified Wingate Anaerobic Test (mWAnT)[33] and an electrocardiogram (ECG) was recorded prior to exercise and during 30 minutes of recovery. Additionally, the Perceived Recovery Status (PRS) scale was administered every five minutes to determine subjects' affect during recovery[28]. Subsequently, an additional mWAnT was performed to investigate post-recovery performance.

Ⅱ. Methods

1. Experimental Approach to the Problem

This was a single-blind repeated-measures experimental study with randomized trials. An Analysis of Covariance (ANCOVA) with repeated measure was used to investigate the effect of a DPV576 recovery garment on recovery indices after the mWAnT. The independent variables consisted of the experimental DPV576 recovery garment and sham garment which appeared to be identical to the experimental garment, but without DPV576. The dependent variable consisted of HRV time-domain and frequency-domain measures, HRR, the PRS scale, and mean and peak power of the post-recovery the mWAnT. Due to the lack of literature on the use of DPV576 during recovery, an a-priori power analysis was not feasible.

2. Subjects

Thirty healthy young adults (Males: n=15; Age 23.7±4.1; Females: n=15 Age 23.2±3.0) from the University of Hawaii at Manoa and surrounding Honolulu community participated in this study. Subjects' 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[13]. The procedures used in the present study were approved by a university institutional review board committee on human subjects. Prior to data collection, informed consent was obtained and subjects read and signed the consent form.

Table 1. Subject Demographics (mean±SD) (n=30).

Gender	Age (years)	Height (cm)	Body Mass (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

Note: BMI= Body Mass Index.

3. Garments

All experimental and sham garments (shirts and long tights) used in this study were provided by Venex Co., Ltd. (Kanagawa, Japan). The subjects were blinded as to which garments had the DPV576 materials. The experimental garment (EG) consisted of polyester (with DPV576 fiber materials) and polyurethane. The sham garment (SG) 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.

4. Procedures

The testing sessions were performed in the Human Performance Laboratory at University of Hawaii at Manoa. Upon arrival the subjects were given an informed consent form, Pre-Participation Medical History Form and Physical Activity Readiness Questionnaire to fill out. The American College of Sports Medicine (ACSM) guidelines for contraindications and termination of exercise testing were strictly followed[13]. An investigator walked through all testing procedures with each subject to familiarize them with the protocol. Anthropometric data, including body mass, 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 asked to lay supine on a treatment table and relax for 20 minutes prior to start of the first mWAnT trial (mWAnT1). The ECG was monitored throughout the 20 minute period. The inter-beat intervals were recorded for last 5 min to determine HRV. The resting HR was measured prior to the mWAnT1 using a heart rate monitor (Polar Heart Rate Monitor FT1 Wrist Receiver T31 Transmitter, Oulu, Finland). The Ratings of Perceived Exertion (RPE) data were collected pre- and post-mWAnT1. The subjects then performed 20-second mWAnT1 on a cycle ergometer. Immediately after a completion of the mWAnT1, the subjects were instructed to change into either EG or SG as quickly as possible, and then lay supine on a treatment table and rest for 30 minutes. The perceived recovery status (PRS) scale[28] was taken at every five minutes after exercise. Post-mWAnT1 HR was also measured at every five minutes post-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 from five to 30 minutes post-exercise. After 30 minutes of recovery, the subjects were instructed to remove the garment and change into original clothes they wore during the mWAnT1. Then subjects performed a second mWAnT (mWAnT2) followed by a five-minute cool-down. In order to compare the two conditions, the subjects performed a total of two testing sessions, which were separated by at least seven days. The garment application was randomized and the subjects were blinded as to which garment they would be wearing.

1) Wingate anaerobic test protocol.

A Monark Ergomedic 834E Cycle Ergometer (Monark Exercise AB, Vansbro, Sweden) was used during the repeated bouts of the mWAnT (mWAnT1 and mWAnT2). The seat position was adjusted for each subject so at the bottom of each pedal stroke the knee was near full extension with the foot in plantar flexion. The handlebars were positioned for each subjects' comfort. All seat and bar position parameters were recorded for reproducibility for the 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 mWAnT began with a three-second countdown by the investigator as the subjects begin pedaling as fast as possible. A resistance weight (0.10 kp * body mass in kg) was quickly applied to the flywheel, using the basket technique. The subjects were encouraged to pedal as hard and fast as possible for the entire 20-second test without pacing themselves. Power outputs were recorded every second throughout the 20-second test using commercially available photoelectric data collection system (SMI Power 2000, ver.1.02; Sports Medicine Industries, Inc., St. Cloud, MN, USA). The RPE data were collected using Borg's 6-20 RPE scale to assess the subject's perceived effort at the end of the each mWAnT[3)]. Immediately after the mWAnT1, subjects were instructed to put on the garment and ECG electrodes were applied after they changed clothes. Subsequently, the subjects began the 30-minute supine recovery period without an active cool down.

2) HRV collection protocol.

Heart rate variability was evaluated twice (Pre and Post mWAnT1) 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 domains 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 electrodes placement. Electrodes were placed on the palmar side of the wrists between ulnar and radial styloid processes and on inferior to the 10^{th} rib along the midline of the nipple. The investigator cleaned electrodes placement sites with an alcohol prep. The subjects were then instructed to lay supine and relax on a treatment table for 20 minutes for Pre-mWAnT1 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 mWAnT1. For the post-mWAnT1 HRV measurement, the ECG leads were replaced on the same sites by the investigator. The investigator continued to monitor ECG throughout the 30 minutes recovery period and record it from five-minutes post-exercise until the end of the recovery period for 25 minutes. Once recording was finished, 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 domains variables. Frequency domains were established using Fast Fourier Transformation spectral analysis. Premature heart beat data were eliminated by the investigator prior to the HRV analysis.

3) Garment application protocol.

The type of the garment was assigned in a randomized 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 mWAnT1, the subjects were instructed to change into either EG or SG 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 mWAnT1, 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 workout clothes before they started mWAnT2. Each garment was collected after the testing session by the investigator and washed after each trial.

5. Statistical Analyses

Data were analyzed by using SPSS version 19 (SPSS Inc., Chicago, IL). Statistical significance was determined at an alpha level of $p < 0.05$. Descriptive statistics and correlations were generated. Two, 2 x 5 ANCOVA with repeated measures were utilized to analyze the HRR, HRV time and frequency domain data (covariate was peak power obtained from mWAnT1). Two, 2 x 6 ANOVA with repeated measures were used to analyze PRS and HR recovery. Four, 2 x 2 ANOVA with repeated measures were applied to analyze the performance of the mWAnT between trials. Trend analysis using orthogonal contrast coefficients was applied to frequency domain data.

Ⅲ. Results

1. Heart Rate and Heart Rate Variability

Averaged HR data during recovery period for both conditions were presented in Table 2. No significant differences between garments were found for post-exercise HR. Averaged data for both time and frequency domain variables collected before mWAnT1 and during 30-minute recovery period are presented in Tables 3 and 4. No significant differences were found for HRV time and frequency variables between garments. The trend analysis suggests that significantly different linear trends during recovery for LF-HF ratio between garments exist (F=4.04, p=0.047), which is indicated in Figure 1. No significant differences in trends were revealed for HF power or rMSSD (Figures 2 and 3).

Table 2. Summary Table of Averaged Data for HRR (Means±SD).

	Condition	Resting	Peak HR	5min-post	10min-post	15min-post	20min-post	25min-post	30min-post	*F*	*p*
HR	EG	60.1±10.1	165.2±10.0	86.3±13.1	85.4±12.0	83.7±13.3	78.6±12.2	76.9±12.1	75.1±11.3	0.852	0.514
	SG	63.3±10.1	163.6±9.9	87.0±13.4	85.7±12.9	81.3±18.8	80.3±12.7	77.1±12.1	74.5±11.2		

Note: EG= Experimental Garment, SG= Sham Garment, HRR=Heart Rate Recovery

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

	Condition	Baseline	5min-post	10min-post	15min-post	20min-post	25min-post	*F*	*p*
MeanRR (msec)	EG	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
	SG	976.3±150.7	703.5±104.3	723.0±104.5	753.1±103.1	781.6±103.2	798.3±105.0		
SDNN (msec)	EG	63.0±29.0	28.3±10.9	26.9±9.6	31.2±11.3	36.8±17.3	37.3±15.3	0.408	0.803
	SG	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)	EG	76.0±39.2	31.9±11.2	29.5±11.0	33.1±12.6	39.9±21.9	37.5±14.9	1.014	0.401
	SG	64.5±35.0	32.8±15.0	30.4±12.3	30.6±9.4	35.6±14.9	37.9±21.0		
pNN50 (%)	EG	42.9±19.4	12.1±10.2	10.4±9.9	12.6±10.6	16.5±13.6	15.6±12.0	0.726	0.575
	SG	35.6±19.2	11.2±10.2	10.3±9.7	10.7±8.0	13.8±9.6	15.8±12.7		

Note: EG= Experimental Garment, SG= Sham Garment, 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= percentage of successive interval differences larger than 50ms

Table 4. Summary Table of Averaged HRV Frequency Domain Data (Means ± SD).

	Condition	Baseline	5min-post	10min-post	15min-post	20min-post	25min-post	*F*	*p*
LF Power (ms)	EG	1975.4±2782.6	366.4±345.6	349.3±305.6	477.5±361.8	745.2 ±784.0	763.0±854.0	1.01	0.403
	SG	1447.5±1189.0	246.7±229.6	377.6±357.0	503.3±527.6	735.7±563.6	947.7 ±1093.2		
HF Power (ms)	EG	2474.0±2713.2	316.9±302.3	257.5±240.6	307.9±242.3	554.2±808.0	484.2±419.2	0.414	0.799
	SG	2046.3±3358.6	303.5±339.4	273.7±280.2	297.6±244.0	456.7±544.3	573.1±1054.5		
LF Power (n.u.)	EG	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
	SG	48.7±18.9	45.5±16.4	55.4±20.1	56.1±22.5	62.3±17.1	59.2±21.0		
HF Power (n.u.)	EG	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
	SG	50.9±19.2	54.5±16.4	44.6±20.1	43.9±22.5	37.7±17.1	40.8±21.0		
LF/HF	EG	1.0±0.7	1.3±0.9	1.6±1.3	1.8±1.1	1.8±1.3	1.8±1.2	1.28	0.279
	SG	1.3±1.2	1.0±0.7	1.7±1.2	2.1±1.8	2.3±1.7	2.2±1.8		

Note: EG= Experimental Garment, SG= Sham Garment, LF Power= power in low frequency range, HF Power= power in high frequency range, LF/HF= LF/HF= Ratio of LF [ms2] over HF Power [ms2]n.u.= normalized unit

2. Perceived Recovery Status

Table 5 presents the average scores of PRS scale. The scores with EG were consistently higher over the time. However, there were no significant differences for PRS. Although no significance was found, a curvilinear trend was observed in PRS scores after mWAnT1 (Figure 4). Table 6 presents correlations between PRS scores and selected HRV indices.

Table 5. Summary Table of ANOVA for PRS Scale Data (Means ± SD).

	Condition	5min-post	10min-post	15min-post	20min-post	25min-post	30min post	*F*	*p*
PRS Score	EG	4.8 ± 2.1	6.3 ± 1.8	7.4 ± 1.7	8.0 ± 1.5	8.4 ± 1.5	8.6 ± 1.3	0.132	0.982
	SG	4.4 ± 1.6	6.0 ± 1.9	6.9 ± 1.7	7.7 ± 1.6	8.1 ± 1.5	8.4 ± 1.4		

Note: EG= Experimental Garment, SG= Sham Garment, PRS= scores of perceived recovery status scale.

Table 6. Summary table of correlation between PRS and selected HRV indices.

	PRS vs. rMSSD	PRS vs. HF Power	PRS vs. LF/HF
EG	*r* = 0.73†	*r* = 0.69†	*r* = 0.96†
SG	*r* = 0.57†	*r* = 0.74†	*r* = 0.98†

†=Correlation was statistically significant, p<0.01

3. Performance of mWAnT

The results of mWAnT variables were presented in Table 7. No significant differences were found between the conditions of the garment. The mean peak power for males was 717.4 ± 137.5 and for females was 482.2 ± 96.6.

Table 7. Summary Table of ANOVAs for mWAnT Data (Means ± SD).

	Condition	mWAnT1	mWAnT2	*F*	*p*
Mean Power (W)	EG	488.6 ± 146.7	491.2 ± 157.6	0.028	0.868
	SG	486.9 ± 145.7	490.9 ± 146.9		
Peak Power (W)	EG	610.3 ± 179.8	597.7 ± 189.0	0.021	0.885
	SG	599.8 ± 167.1	585.7 ± 167.9		
Minimum Power (W)	EG	373.3 ± 134.0	391.6 ± 134.0	0.003	0.956
	SG	363.0 ± 156.6	382.3 ± 134.6		
Decrease (%)	EG	39.4 ± 10.4	34.7 ± 7.1	0.004	0.948
	SG	40.4 ± 15.7	35.4 ± 9.3		

Note: mWAnT1= First modified Wingate Anaerobic Test, mWAnT2= Second modified Wingate Anaerobic Test.

Ⅳ. Discussion

This study was conducted to assess the effect of DPV576 coated recovery garments on the HRR and parasympathetic tone 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 EG and SG garments during recovery in terms of HRR (p=0.514) or autonomic nervous system activity after a high-intensity, 20-second bout of anaerobic exercise. Parasympathetic modulation significantly increased during recovery period (p<0.001), but was not significantly different between the trials. Although the ANCOVA failed to reveal significant main effects or interactions between garments, the trend analysis suggests that significantly different linear trends during recovery for LF-HF ratio between garments exist (F=4.04, p=0.047), indicating the EG resulted in lower sympathetic tone over time compared to the SG (Figure 1). However, no significant differences in trends were revealed for HF power or rMSSD (Figures 2 and 3). Therefore, under the condition of the present study the HRV indices indicating parasympathetic tone (rMSSD and HF power) did not appear to be enhanced by the EG.

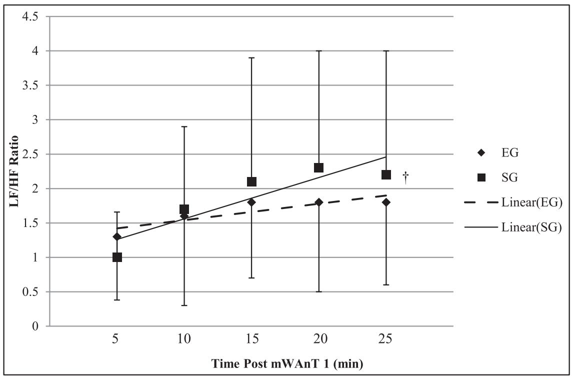
Data during the half hour of recovery period were similar to those reported by Javorka et al.[25], who studied a comparable population. In concordance with their study, HR decreased gradually in the present study, but did not return to pre-exercise values after 30-minute recovery period. Time domain HRV indices are very similar between the studies in the magnitude and shape of the recovery curve. Therefore, data from the present study were judged to be reasonable indices of HRV during recovery.

In this study, HRV time and frequency domain was utilized to investigate the effects of DPV576 coated garments on parasympathetic activity. Kannankeril et al.[26] found that immediately post-exercise parasympathetic tone increased until four minutes and remained constant until 10 minutes of recovery. Immediate autonomic change was not recorded in present study because our subjects needed to change into the garments after the mWAnT1. 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[5] suggested not collecting HRV until after five minutes post-exercise due to unstable data.

The manufacturer of the EG 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 type of garment. Goldberger et al.[21] 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 (Figures 2 and 3). This finding was similar to other previous studies, which reported an increase in parasympathetic drive after exercise[6, 8, 20, 30]. As can be seen in Figure 2, HF power actually decreased slightly after 10 minutes of recovery and gradually rose. This response has been previously reported by Takahashi et al.[34] and Javorka et al.[25]. 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[5].

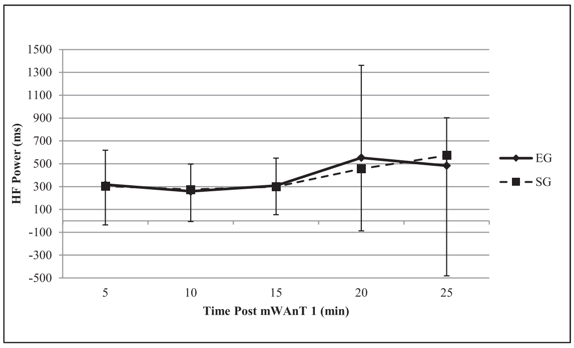
Low frequency power is often described as representing both parasympathetic and sympathetic activity; whereas the ratio of LF-HF represents sympatho-vagal balance, allowing HRV to be used as an index of autonomic responsiveness, with higher values reflecting sympathetic dominance[4]. The ratio of LF-HF increased over the recovery period for both conditions indicating an increase in sympatho-vagal balance, although the linear trends were significantly different. This increase in sympatho-vagal balance was possibly due to the anticipation of mWAnT2 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 EG was a gradual positive slope compared to a steeper slope for the SG. 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 4). 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 rest due to training[35]. Pierpont et al[30] 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

Laurent et al.[28] created and assessed the practical utility of PRS scale to identify individuals' level of recovery after exercise (1-10 Likert scale). In their 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'



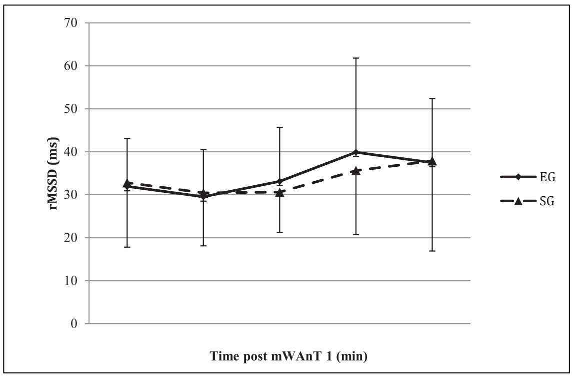
Note: EG= Experimental Garment, SG= Sham Garment, LF/HF= Ratio of Low Frequency [ms2] over High Frequency Power [ms2], mWAnT1= First modified Wingate Anaerobic Test; †=Linear trends were significantly different at *p*<0.05.

Figure 1. mChanges in LF-HF Ratio During Recovery Period after mWAnT 1.



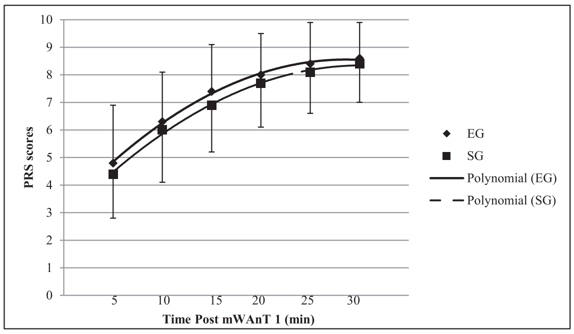
Note: EG= Experimental Garment, SG= Sham Garment, HF=High Frequency, mWAnT1= First modified Wingate Anaerobic Test

Figure 2. Post mWAnT1 changes in HF power (ms).



Note: EG= Experimental Garment, SG= Sham Garment, rMSSD= the square root of the mean of the sum of the squares of differences between adjacent NN intervals, mWAnT1= First modified Wingate Anaerobic Test

Figure 3. Post mWAnT1 changes in rMSSD (ms).



Note: EG= Experimental Garment, SG= Sham Garment, PRS= scores of perceived recovery status scale

Figure 4. Post mWAnT1 changes in PRS Scores.

recovery status after exercise. In the present study, PRS scale was utilized to identify subject's perception of recovery status at five-minute intervals after the mWAnT1. The scores of PRS gradually improved over the recovery period (see Figure 4) and were significantly correlated with indices of HRV (see Table 6). The average score of PRS 30 minutes after the mWAnT1 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 mWAnT1 and mWAnT2 (see Table 7). 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 (see Table 6). Thus the results from the present study support the validity of PRS scale.

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 mWAnT. In present study, a single 20-second mWAnTs was 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[33]. Post-mWAnT 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 mWAnT1 based on the Gellish's second equation[14] which has previously been shown to accurately predict maximal HR in this population[10]. Although subjects achieved nearly maximum HRs after the 20-second mWAnT1, this exercise test may have not caused fatigue especially for physically active subjects. Additionally, the male subject's mean peak power value was above the 55th percentile, and females achieved a mean peak power above the 60th percentile when compared to a previous study[29]. This supports the fact that the subjects put forth a good effort.

In summary, no significant differences were revealed for HRR, HRV time and frequency domain analysis between the DPV576 coated garment and sham garment. Within limitation of this study it was concluded that DPV576 coated garment had no effect on HRR, HRV, PRS and performance of mWAnT2. It was also concluded that the PRS scale provides valid recovery status based on HRV results.

PRACTICAL APPLICATION

There is a paucity of research on the effectiveness of the DPV576, as the DPV576 has been a recent addition to the choice of materials used in garments purposed to promote quicker recovery. The design of present study did not demonstrate that the DPV576 altered recovery during the immediate 30-minute recovery after the intense exercise. Future research should investigate its effect on the longer-term recovery period as the current study only investigated the immediate effect. Recovery may be enhanced during a 24 hour period, as was indicated by the significant difference in linear trends.

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