Physical fitness and psychological hardiness as predictors of parasympathetic control in response to stress. A Norwegian police simulator training study.

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Abstract

The individual biopsychological response to a specific stressor is the result of a complex interplay between many different factors including physiology, behavior, and personality. The goal of the present study was to explore the potential link between physical fitness, hardiness (Kobasa,1979), and the individual autonomic stress arousal experienced during a stressful police training situation (active shooter).

Eighty-four police students participated in the study and were randomly assigned to either a High-Stress or a Low-Stress testing condition. Hardiness was measured with the Dispositional Resilience Scale (Hystad et al.,2010). Physical fitness was assessed with $\dot{V}O_{2max}$. Parasympathetic control was measured using heart rate variability (HRV), i.e., the root Mean Square Successive Difference (RMSSD). Regression analysis showed that psychological hardiness had a negative main effect on change in parasympathetic activity from baseline to the testing phase (B = -1.43, t = -2.81, p=.007). Larger withdrawal of parasympathetic activation for high-hardy individuals in this phase of the study can be interpreted as an adaptive adjustment to the task set in front of them. A second regression analysis showed that both psychological hardiness (B = -1.47, t = 3.68, p < 001.) and physical fitness (B = 0.89, t = 2.85, p = .006) had significant main effects on change of parasympathetic activity entering the recovery phase of the study. Both regression coefficients were positive, with higher scores on hardiness and physical fitness predicting greater parasympathetic activation at stress offset.

Overall the results suggest that psychological hardiness and physical fitness may be important factors in how operational stress affects the individual in a police setting. Those high in hardiness and good physical form seem to be better able to recuperate and reset after a stressful incident, something that can be vital in an operational context. These results will be discussed in relation to the existing literature in the field.

Keywords: Stress, Hardiness, Physical fitness, Police, Parasympathetic control

1. Introduction

There is no universal consensus on the definition of *stress*, and numerous definitions of stress have been proposed (Cohen, Kessler, & Gordon, 1995; Segerstrom & Miller, 2004). What most researchers on the topic seem to share is “an interest in a process in which environmental demands tax or exceed the adaptive capacity of an organism, resulting in psychological and biological changes that may place persons at risk for disease” (Cohen, et al., 1995, p. 3).

While most, or all, people experience stress from time to time, stress is a part of the daily experience in operational police work (Van Hasselt, et al., 2008). Many operational police situations involve uncertainty and potential for danger, not only for oneself but also for others. Uncertain conditions are indeed an essential part of the job description for police officers. Not only is stress an occupational hazard in the police that potentially can have adverse health effects for the individual police officers, but how effectively they cope with uncertainty and acute stress can also significantly affect the officers’ efficiency in their work.

1.1. Psychological hardiness

Psychological hardiness refers to a set of personality characteristics that appear to protect individuals from the adverse effects of stress (Bartone & Hystad, 2010; Kobasa, 1979). As typically defined, hardiness describes a generalized style or mode of functioning characterized by a strong sense of *commitment*, *control*, and *challenge* (Bartone, 2000; Bartone & Hystad, 2010). Commitment refers to a generalized sense of purpose and engagement in life. A person high in commitment is predisposed to interpret interaction with people and events as exciting and worthwhile, and to seek active involvement rather than withdrawal. Control entails a belief in one’s own ability to influence the course of events. Challenge involves seeing new events and challenges as inherently meaningful and opportunities for development and personal growth (Bartone, 2000; Maddi, 2002). Combined, the personality characteristics associated with hardiness are believed to decrease the negative impact of stress through a combination of underlying cognitive, physiological, and behavioural factors (Bartone, Johnsen, Eid, Hystad, & Laberg, 2017; S. W. Hystad, Eid, & Brevik, 2011).

In the past 40 years, an extensive body of research has accumulated that demonstrates that hardiness protects against the ill effects of stress on health and performance across a wide range of domains. A meta-analysis by Eschleman, Bowling, and Alarcon (2010) summarized some of this research, and concluded that hardiness is an important and unique stress-resiliency resource. Importantly, the meta-analysis confirmed that hardiness explained unique variance over other common dispositions, including five factor model traits, in all but one of the analyses, and emerged as the strongest explanatory variable in 70% of the analyses.

Although previous studies have shown that hardiness emerge as a protective factor against psychosocial distress among police officers (e.g. Andrew, et al., 2008; Barton, Vrij, & Bull, 2004; Fyhn, Fjell, & Johnsen, 2017; Potard, Madamet, Huart, & El Hage, 2017), some qualifications are in order. The majority of this research has been cross-sectional (for a review, see Janssens, van der Velden, Taris, & van Veldhoven, 2018) and therefor only an association, and not causation, can be inferred from these studies. Recent years have however seen an increase in prospective and longitudinal studies among police and other high-risk professions, and the results from these studies are more mixed. Two recent studies employing a prospective design found that measures of psychological resilience either did not predict mental health from baseline to follow-up (Jenkins, Allison, Innes, Violanti, & Andrew, 2018) or that the predictive value of psychological resilience measures declined over time (van der Meulen, van der Velden, Setti, & van Veldhoven, 2018). In contrast, a recent study among

U.S. Army combat medics found that psychological hardiness significantly predicted better mental health (less depression and fewer post-traumatic stress symptoms) over a period of three years (Krauss, et al., 2018). Clearly, more longitudinal and experimental research is needed to assess the predictive value of psychological hardiness in the police and similar high-risk occupations.

The primary focus in previous studies among police officers has been on physical and mental health. However, there is some evidence suggesting that hardiness might also affect police officers' performance in frontline police work. In a simulation study by Barton, Vrij, and Bull (2004), officers low in hardiness made more errors when confronted with an armed suspect (i.e., shot the suspect in a difficult to justify shooting incident) than officers high in hardiness.

That the individual's cognitive appraisal of a stressor has an impact on the stress response is well established in the literature (Eriksen, Murison, Pensgaard, & Ursin, 2005; Lazarus & Folkman, 1984; Ursin & Eriksen, 2004). Kobasa (1982) early on emphasised that the effect of hardiness is, at least partly, mediated by cognitive appraisal mechanisms. A more optimistic cognitive appraisal will influence how the individual behaves and reacts to an event. More beneficial coping styles are believed to decrease the impact of the stressors on the individual, which also is thought to lead to more adaptive biopsychological stress activation. This will include a reduced response in the sympathetic nervous system. Some support for a link between hardiness and altered biopsychological responses can be found in the literature. Both Contrada (1989) and Wiebe (1991) found that participants scoring higher on hardiness exhibited lower cardiovascular reactivity in response to laboratory-induced stress. Allred and Smith (1989), in contrast, found that hardiness was associated with elevated systolic blood pressure responses to a manipulated stress task. The authors interpreted this elevated stress response as indicative of more active coping efforts.

Hardiness has also been found to be related to more adaptive immune responses, and more healthy cholesterol levels (Bartone, Valdes, & Sandvik, 2016; Dolbier, et al., 2001; Sandvik, Bartone, et al., 2013).

1.2. Physical activity and physical fitness

The physical benefits of exercise and training for police officers are more or less evident as the job often involves running and other physically strenuous tasks. Good *physical fitness* is a part of the entry requirements for the Police University College in Norway, and physical exercise and knowledge about exercise execution and planning is also an essential part of the three-year police education. Regular physical training is recommended to maintain optimal performance of police officers throughout their careers.

That physical fitness and physical activity play an important role in health promotion and maintenance is well established in the literature, and their potential moderating influence on adverse effects of stress has received increasing attention (Sothmann, et al., 1996; Warburton & Bredin, 2017; Warburton, Nicol, & Bredin, 2006). The Cross-Stressor Adaptation Hypothesis (Sothmann, et al., 1996) is a theory suggesting that regular physical exercise will induce an adaptation of the stress response system which will also modify the psychological stress response to non-physical stressors. This cross-stressor adaptation also seems to be related to changes in autonomic self-regulatory processes (Hamer & Steptoe, 2007). A meta-analysis by Forcier et al. (2006) concluded that physical fitness is related to attenuated cardiovascular stress reactivity. In contrast another meta-analysis from the same year (Jackson & Dishman, 2006) concluded that fitness was slightly related to greater cardiovascular reactivity. However, both of these meta-analyses did find physical fitness to be related to faster cardiovascular stress recovery. More recent empirical research has continued to find that physical activity seems to reduce stress reactivity in both male and females in response to psychosocial stress (Klaperski, von Dawans, Heinrichs, & Fuchs, 2013, 2014). These previous studies have used a variety of stress-inducing tasks including mental arithmetic, public speaking, and memory search. The results are somewhat mixed. But as different physiological response patterns are known to be produced by various stressors, it is difficult to generalize findings from one setting to another (Jackson & Dishman, 2006; Klaperski, et al., 2014).

While most studies have looked at either long-term stress or more laboratory-induced cognitive stress, less is known about how physical fitness may influence more acute operational stress reactions. A highly relevant study of exercise intervention on stress reactivity in firefighters (Throne, Bartholomew, Craig, & Farrar, 2000) used a computer simulated fire scene as a stressor and found significant effects of physical training where the exercise-trained firefighters, compared to a control group, reacted to the simulation with significant lower HR and arterial pressure. Another study by Taylor et al. (2008) found aerobic fitness to be inversely related to self-reported subjective distress in response to extreme military survival training. However, both these studies only indirectly measured physical fitness as they relied on self-reported fitness or used an induced training intervention. Neither of them included an objective measure of the individuals' fitness at the point of testing.

1.3. Autonomic regulation and parasympathetic control

The biological reaction to a perceived stressor is an essential element of the adaptive and self-regulating system of the organism (Goldstein & McEwen, 2002; Ursin & Eriksen, 2004). This effort to maintain stability in response to physical and psychological demands in a complex environment is coordinated by the continuous dynamic interplay between the sympathetic (SNS) and parasympathetic (PNS) branches of the autonomic nervous system (ANS) (Porges, 1992b). The SNS is primarily associated with increased metabolism meant to prepare the body for fight-or-flight, including elevated heart rate and heart stroke volume, immune cell redistribution, and increased alertness and arousal of the central nervous system (Cohen, et al., 1995; Groër, Meagher, & Kendall-Tackett, 2010; Lundberg, 1999). This activation to accommodate a stressor is expedient as long as the system again returns to "normal" operation after the challenge. The PNS is a vital part of this recovery process and is associated with decreased arousal, conservation, growth and restoration (McEwen, 2009; Porges, 1992b). The SNS and PNS responses are coordinated continuously to provide the appropriate internal state to meet the demands of the milieu and to keep the internal state within appropriate limits to secure survival. This is also called maintaining homeostasis. Stress may be defined as a disruption of homeostasis, where the standard inhibitory control (parasympathetic control) exerted by the PNS is temporally toned down to allow the SNS to mobilize the resources needed to meet the perceived challenge (Porges, 1992b; Roos, et al., 2017). The control exerted by the PNS is vital for regulating the psychophysiological response to acute stress. The degree of such parasympathetic control has been linked to health, disease and also to cognitive function (Hansen, Johnsen, Sollers, Stenvik, & Thayer, 2004; Roos, et al., 2017; Thayer, Hansen, Saus-Rose, & Johnsen, 2009).

One way to measure autonomic regulation during acute stress is to look at the heart rate (HR), and specifically the heart rate variability (HRV). The measure of HRV is a non-invasive tool that can provide a proxy measure of the autonomic nervous system´s influence on the heart (Porges, 1992a; Thayer, Hansen, & Johnsen, 2010). The HR is determined by the constant interaction between sympathetic and parasympathetic nerves (vagus) at the sino-atrial node of the heart. The time intervals sequence between the heart beats (beat-to-beat) is called Heart Rate Variability (HRV). The root mean square successive difference (RMSSD) is a time domain measure of HRV that is the most commonly used measure derived from such interval differences. The RMSSD is sensitive to short-term high-frequency fluctuation in the HR, and the fast fluctuation of HRV is mostly mediated by the fast parasympathetic action (Berntson, Lozano, & Chen, 2005; DeGiorgio, et al., 2010; Shaffer & Ginsberg, 2017; Task Force Heart Rate Variability, 1996). The RMSSD is often regarded as a snapshot measure of parasympathetic activity, and the return of RMSSD towards baseline (recovery) can be used as a measure of the body's restoration and return to homeostasis after an acute stress reaction (Kamen & Tonkin, 1995; Otzenberger, et al., 1998). RMSSD recovery has also been linked to other markers of physical restoration like clearance of plasma catecholamines, lactate, and other metabolic byproducts (Flatt, Esco, & Nakamura, 2017; Stanley, Peake, & Buchheit, 2013).

1.4. The aim of the study

The present study aimed to examine the link between physical fitness, psychological hardiness and parasympathetic control (measured through HRV) during acute stress in operational police settings. We hypothesized that both higher physical fitness and psychological hardiness would be related to higher parasympathetic control during stress. We also hypothesized that the effects of individual differences in fitness and psychological hardiness on the stress response would be more pronounced during higher stress load. This is because individual coping mechanisms will be more salient when the demands are high.

2. Method

2.1. Participants

Of a total of 168 final-year police students at the Stavern division of the Norwegian Police University College, 90 students were recruited to participate in the study. The sample size was based on previous comparable studies in the field (i.e. Hansen, et al., 2004; Saus, et al., 2006) and a prior power analysis suggesting a group size of 51 with a significance level of 5, power of 08 and a medium effect size (.50). A convenience sample was used, and we included the first 45 males and the first 45 females who volunteered to participate. No monetary or other incentives were offered for participation. Before the data collection started, a total of six participants of the initial 90 withdrew from the study, all because of injuries or illnesses that prevented them from participating (n=84). The age of the participants ranged from 22 to 33, with a mean of 24.25 years. All the participants had some previous experience using the simulator as a port of their education, but not with the scenario used in the study.

2.1.1. Norwegian police and police education: The Norwegian Police University College is the central education institution for the Norwegian Police. The University College offers a three-year bachelor's degree program in police study, in-service training and post-graduate studies, including a master program in police science. The participants in this study were final-year students in the bachelor's degree in police science program. The education intends to provide a broad theoretical and practical foundation for police work. After finishing the degree, graduates are qualified to apply for jobs as police officers in Norway.

The Norwegian Police are generally not armed but have access to firearms in their police cars and can arm themselves if ordered to do so, or without an order if the urgency of the situation demands it.

2.2. Apparatus

2.2.1. Physical fitness ($\dot{V}O_{2max}$). One well recognized objective measure of physical fitness is maximal oxygen consumption ($\dot{V}O_{2max}$). $\dot{V}O_{2max}$ is a major part of cardiorespiratory fitness and reflects the physical fitness of an individual. To measure $\dot{V}O_{2max}$ in the present study, we used indirect calorimetry, which yields results comparable to the "gold standard" direct calorimetry in humans (McArdle, Katch, & Katch, 2015). The $\dot{V}O_{2max}$ test was performed in a laboratory at Vestfold Hospital Trust, as an incremental treadmill test on a Woodway ELG 55 treadmill (Waukesha, Germany). The treadmill test was conducted with a standard inclination of 5%, and velocity was increased every 30 seconds, until voluntary exhaustion. The duration of the test ranged between 4 and 8 minutes. A similar protocol, which use a fixed inclination and only increase in velocity previous used in healthy individuals (Helgerud, et al., 2007; Storen, et al., 2017). Oxygen uptake was registered using the Jaeger oxycon pro ergospirometry test system (Jaeger Oxycon Pro JLAB 5.x, Hoechberg, Germany). The system includes a mixing chamber with oxygen (O_2) and carbon dioxide (CO_2) analyzed continuously every 10 seconds. Before each test, the device was checked and calibrated with room air and a certified gas containing 16% O_2 and 4% CO_2. Volume calibration was performed before each test, with a 3-L automatic syringe (Hans Rudolph). A face mask (Hans Rudolph V2 mask) was used to collect expired air during the test and HR was collected continuously through the tests with Polar WearLink+ H7 Bluetooth and Polar RCX 5 (Polar RCX 5, Polar Electro OY, Finland). $\dot{V}O_{2max}$ was considered established when the flattening of the oxygenuptake curve occurred, with secondary criteria being voluntary exhaustion and respiratory exchange ratio (RER) $\geq$1.05. Maximal oxygen uptake was calculated from the highest 10 seconds measurement interval and the two neighboring values, and the maximal HR was registered as the highest observed. The participants were instructed to refrain from eating and smoking 2 hours and 4 hours before measurements, only drink water, and to refrain from high intensity exercise the last 24 hours before measurements.

2.2.2. Psychological Hardiness. Psychological hardiness was assessed with the Norwegian adaptation of the Dispositional Resilience scale (DRS-15-R; Hystad, Eid, Johnsen, Laberg, & Bartone, 2010). The DRS-15-R consists of 15 positive and negative statements. Participants are asked to indicate on a 4-point Likert scale how true or not true they consider each statement is about them. The included statements cover the three conceptual hardiness facets commitment, control and challenge. Higher scores on the DRS-15-R scale reflects more psychological hardiness. The Cronbach's alpha for the DRS-15-R in the present sample was .753 for the total score, and .710, .732 and .616, respectively, for the dimensions Commitment, Control and Challenge.

2.2.3. Heart Rate (HR) and Heart rate variability (HRV). Parasympathetic control was measured by registering HR and HRV using the Actiheart System 4.0 (Cambridge Neurotechnology Ltd; Brage, Brage, Franks, Ekelund, & Wareham, 2005), a compact, lightweight device that records HR and variability of R-R interbeat intervals (IBI). The Actiheart clips onto a single ECG electrode (FS-521 Skintact®) with a short ECG lead to another electrode that detects the ECG signal. The analogue signal was processed using a band-pass filter (10-35 Hz, sampled with a frequency of 128 Hz. Artifacts in IBI were screened for and handled in the Actiheart 4.0 program manually.

The Actiheart recorder was placed on the upper chest. We monitored HR and HRV continuously from 5 minutes before testing to 5 minutes just after the testing. We split the HRV data into three timeslots: baseline (5 min before testing), simulator (ca 2 min), and recovery (5 min after testing). The HRV data within each timeslot were aggregated for analysis.

The RMSSD component of HRV was used as a measure of parasympathetic activity (Kamen & Tonkin, 1995; Otzenberger, et al., 1998). RMSSD is less sensitive to variations in respiratory patterns compared to other HRV components (Laborde, Mosley, & Thayer, 2017; Penttila, et al., 2001) which makes RMSSD especially suitable when breathing rate might interfere, e.g. during movement or exercise. Cardiac ANS activity, including the amplitude, is highly specific to each individual (Garet, et al., 2004). Therefore, we calculated the individual magnitude of percentage change in RMSSD between each phase of the study (Stanley, Buchheit, & Peake, 2012). This calculation created two new variables. One for the percentage of RMSSD change from baseline to the testing phase (RMSSD Simulator – RMSSD baseline/ RMSSD Baseline), and a second one for the percentage of RMSSD change from the testing phase to recovery (RMSSD Recovery – RMSSD Simulator/ RMSSD simulator). By using the individual´s change in RMSSD activity each participant act as their own control, and we obtain a measure of how each regulated his or her autonomic activity to changing circumstances in the study. This also reduces the impact of some the possible confounding variables which are known to affect the unstandardized RMSSD score like age, gender, nicotine, caffeine, and circadian rhythm.

2.2.4. Training Simulator. The simulator used in this study was a MILO® Range 4.8. Shooting Simulator produced by IES Interactive Training. The system uses video and interactive technology to simulate realistic environments and situations for practicing use of firearms. The scenario used in the study was an active shooter situation in a school setting. The scenario included graphically violent scenes involving the shooting of students. There were a total of three consecutive shooters at the scene, and the participants had to eliminate each perpetrator to advance in the scenario successfully. The scenario stopped after the successful elimination of the third shooter or if the participants were shot by one of the perpetrators in the scenario. To ensure that all participants were exposed to a minimum of the scenario, we, without the participants' knowledge, remotely assisted the participants on the takedown of the first shooter. Of the 84 participants, 71 participants were assisted in the takedown of the first shooter (36 in the High-Stress condition and 35 in the Low-Stress Condition). There are multiple reasons for the need for such assistance. One reason is the lack of shooting skills. These students did not yet have extensive shooting practice (this comes towards the end of the education). Most of the training they had received at the time point of our study were scenario based and with a focus on when it is feasible and legal to use firearms. Other reasons for the need to assist is more of a technical nature. The shots fired is not always registered by the system, and the "hit zones" defined in the scenario is ferally limited (e.g., a shoot in the legs of the perpetrations will not be registered as hits). The weapon used in the simulator was a Heckler & Koch P30L modified for use in the simulator. Heckler & Koch P30L is the standard firearm used in the Norwegian police.

2.3. Procedures

The study was approved by the Norwegian Centre for Research Data (NSD). All participants signed an informed consent statement and were informed of their right to withdraw from the study at any time.

Participant flow diagram and study design are illustrated in figure 1. In the first phase of the study, all participants were tested for physical fitness using a treadmill and $\dot{V}O_{2max}$ measuring procedure. All $\dot{V}O_{2max}$ measures were obtained within a two to four-week timeframe before the simulator test. At this time they also completed a selection of self-reports including questions regarding demography, general health, and the DRS-15-R. Before the second phase, the participants were randomly assigned, while matched on gender, to two different testing conditions; Low-Stress and High-Stress. The participants were not informed about which test condition they were assigned to, and were only given a time, date and location for the next test.

2.3.1. High-Stress condition. The participants in the High-Stress group were exposed to a physical and mental stress enhancing condition before the main test in the simulator. The participants were told that they should pack their gear and get ready for a «normal» day on patrol. A silent partner (experienced police officer) drove the patrol car, and the study participant was seated in the front passenger seat. The participants were told that the silent partner would only drive the car and would not interact or get out of the car. The participants were to communicate with dispatch on the radio, and to respond as a one-person patrol. Once they left the car, they were on their own. In the car, they were asked by dispatch to drive to a given address in response to a report of domestic disturbance in an apartment. The apartment was located on the third floor, and when the participants reached the top the stairs on the right floor, they received an urgent call from dispatch to abort the initial assignment as they had received calls of shots fired at a neighboring high school (building with the training simulator). The participants were then instructed by dispatch to go down to the car, put on protective gear, arm themselves and head off on foot to the school which was right by the apartment building (about 50m /165ft). They were told and heard on the radio that other patrols were on the way, but they were the first on the scene and had to act immediately to save lives. At the school gate, they could also hear shots fired. To open the gate they need to use a four digit code given to them over the radio. Once in the school building, the scenario was briefly paused (about 30 seconds) and the participants were led to the room with the training simulator and their gun was exchanged to a gun (laser) designed for the simulator. In the simulator room, they were told that they were back at the entrance of the school and were to act accordingly.

2.3.2. Low-Stress condition. The participants in the Low-Stress group met at the training simulator (room adjacent to the simulator) and were only given an oral instruction. They were informed that several calls had been received regarding shots fired at Stavern High School. They were the first patrol on the scene and had to act immediately to save lives. They already wore protective gear and were also given a gun (simulator gun). The scenario started once they entered the simulator room.

To check the effect of the stress condition manipulation the participants were asked (right after the testing) to rate on a scale between 0 - 10 how stressed they felt right before entering the simulator (testing phase). There was a significant difference (t(83)=4.343, $p<.001$) in the reported subjective stress between the Low-Stress (M = 3.34, SD = 1.76) and High-Stress (M = 5.08, SD = 1.92) groups. The same effect is seen regarding (Beats Per Minute; BPM) where there is no significant difference at baseline but a significant difference in the simulator and at recovery (for details see result section and table 2).

RMSSD baseline and recovery were recorded for both test groups for a 5 min period *before* and 5 min period shortly *after* the testing phase. The participant was seated during these periods and asked to try to relax as much as possible.

2.3. Analyses

The overall objectives of the analysis selected were to assess how the individuals' parasympathetic reactivity in an operational acute stress condition was predicted by psychological hardiness and physical fitness. The endpoints in the study are the individual percentage of change in RMSSD between the phases of the experiment. The RMSSD variables were log-transformed to achieve a more normal distribution before the statistical analyses.

Cronbach´s alpha was used to assess the reliability of all measurements. Independent sample t-test was used to check the effect of the stress condition manipulation. Pearson's product-moment correlation was also used in the preliminary analyses to examine the relationships between the main variables in the study. Multiple regression analysis using the direct entry method was conducted to investigate the predictive power of physical fitness and psychological hardiness on RMSSD. To test our hypotheses, we performed multiple regression analyses using a sequential method of entry. In the first block, we entered condition (low- vs. high-stress), psychological hardiness (total score) and physical fitness. In the second block, we entered two multiplicative interaction terms, one between condition and psychological hardiness and one between condition and physical fitness. All the analyses were performed using Stata version 15.

3. Results

3.1. Descriptive statistics, t-tests, and correlations

Descriptive statistics for all variables are reported in Table 1. Independent-samples t-tests were used to test whether the randomization was successful, and whether the pre stress manipulation had the indented effect. We found no significant differences between the Low-Stress and High-Stress group on the background variables of age, $\dot{V}O_{2max}$, hardiness, and baseline HR and RMSSD. However, the High-Stress group had significantly (*t*(82) = 4.239, *p*<.001) higher average HR (*M*=132.65, *SD*=18.34) during the simulator phase compared to the Low-Stress group (*M*=114.99, *SD*=19.77). All t-tests are reported in table 2.

The correlation analysis revealed several significant correlations between the measures. For the High-Stress group, $\dot{V}O_{2max}$ was positively correlated with RMSSD during recovery (*r*=.519, *p*=.001) and the amount of change in RMSSD from the simulator to recovery (*r*=.345, *p*=.027). The DRS-15-R total score was negatively correlated to RMSSD during the simulator phase (*r*=-.343, *p*=.033) and amount of change in RMSSD from baseline to the simulator phase. There was a positive correlation between DRS-15-R total score and amount of change in RMSSD from the simulator phase to recovery (*r*=-.341, *p*=.033).

For the Low-Stress group there were no significant correlations between $\dot{V}O_{2max}$ and RMSSD, but a significantly positive correlation between DRS-15-R total score and amount of change in RMSSD from the simulator phase to recovery (*r*=.456, *p*=.004).

All correlations are reported in table 3.

3.2. Multiple regression analysis

Changes in RMSSD between the different phases of the study were used as outcome variables in two separate multiple regression analyses. In the first analysis, we used the RMSSD change from baseline to the simulator (test phase) as the outcome variable. In the second analysis, we used the RMSSD change from the simulator to recovery as the outcome variable.

The results of the regression analyses are reported in table 4. The first regression showed that psychological hardiness had a negative and statistically significant main effect on RMSSD change from baseline to the simulator (*B* = -1.43, *t* = -2.81, *p*=.007). Neither condition nor physical fitness had a statistically significant effect on RMSSD change. In total, the model explained 10.3% of the variation in RMSSD change (R^2 = .103). The majority of this explained variation was due to the effect of psychological hardiness (sr^2 = .097). None of the two interaction terms entered in the second block reached statistical significance.

The second regression analyses showed that both psychological hardiness (B = -1.47, t = 3.68, p < 001.) and physical fitness (B = 0.89, t = 2.85, p = .006) had statistically significant main effects on RMSSD change from simulator to recovery. Both regression coefficients were positive, with higher scores on hardiness and physical fitness predicting greater change from simulation to recovery. The effect of condition was also statistically significant (B = -12. 10, t = -3.20, p = .002), with the high-stress group exhibiting less RMSSD change from simulation to recovery. Combined, the three predictors explained about 32% of the variations in RMSSD change (R^2 = .319). Psychological hardiness uniquely explained about 12.6% (sr^2 = .126), physical fitness about 7.5% (sr^2 = .075) and condition about 9.5% (sr^2 = .095). Again, entering the two interaction terms in the second block did not result in statistically significant coefficients.

3.3. Exploring group differences

Although none of the interactions between condition and hardiness and physical fitness was statistically significant, we nevertheless wanted to explore the differences between the low- and high-stress conditions (i.e., simple slopes). The result of this exploration can be seen in figure 2. The simple slopes for physical fitness on RMSSD change from baseline to simulator are as expected relatively flat for both the low- and high-stress groups (upper right panel in figure 2). For the corresponding simple slopes for psychological hardiness (upper left panel in figure 2), it is interesting to note that the slope for the low-stress group was not statistically significant (B = -1.10, p = 118), whereas the slope for the high-stress group was (B = -1.84, p = .02).

The same pattern emerged for the simple slopes for physical fitness depicted in the lower right panel in figure 2. The slope for the low-stress group on RMSSD change from simulator to recovery was not statistically significant ($B = 0.47$, $p = .25$), whereas the slope for the high-stress group was ($B = 1.55$, $p = .002$). Both simple slopes for psychological hardiness depicted in the lower left panel were statistically significant ($B = 1.28$, $p = .019$ for the low-stress group, and $B = 1.78$, $p = .004$ for the high-stress group). Although it must be stressed that the regression analyses already established that none of the simple slopes for the two conditions are statistically different from each other, it is still interesting to note that there are tendencies in the expected, hypothesized direction.

4. Discussion

Individual differences in stress reactivity contributes to the considerable variability seen in how people react to similar external stressors. The present study aimed to examine the link between physical fitness, psychological hardiness and parasympathetic control during acute stress in operational police settings. As hypothesized we found that parasympathetic reactivity during stress was related to both physical fitness and psychological hardiness.

In both the correlational analyses, and in the first regression analyses we find a significant negative relation between psychological hardiness and parasympathetic reactivity in the shift from baseline to the simulator phase for the High-Stress group. This means that high scores on hardiness were associated with a higher withdrawal of parasympathetic activation in the switch from the baseline phase to the simulator phase. This reduction of PNS activity could be interpreted as an indication of a higher individual stress activation to the challenges in the simulator. This because a reduced PNS would allow a more substantial SNS activation (Porges, 1992b).

In many studies of stress and stress responses there seems to be a focus on heightened stress reactivity as predominantly negative, and that higher stress response is then often interpreted as a sign of maladjustment. This might be right when talking about more prolonged and chronic stress activation, but in response to an acute stressor a heightened activation might well be a sign of adaptive adjustment that can energize and promote action and positive coping. Deinstbier (1989) addressed the issues of the timing of arousal and described the stress arousal patterns for emotionally stable and competent individuals with a rapid and strong arousal onset, and fast arousal decline at stress termination. In this regard it is noteworthy that in our findings regrading psychological hardiness it seems to be the commitment dimension of hardiness that is mostly contributing to the positive stress - hardiness association (see correlation in Table 3.) during stress onset. It is indeed natural to think that people who are highly engaged and committed to the task ahead of them will experience a higher stress activation as a result of a more active coping style compared to people with a more passive coping style. One of the hallmarks of an adaptive stress response is a flexible stress response that reacts in a timely way to challenges (Dienstbier, 1989; Gal & Lazarus, 1975; Porges, 1992b). Higher stress activation for high-hardy individuals in this phase of the study can be interpreted as an adaptive adjustment to the task set in front of them. When a police officer is confronted with a situation that demands rapid action, the SNS should be activated to make bodily resources available for action – hence the popular name “fight or flight response”.

Neither condition (High or Low Stress) nor physical fitness effected the change in PNS activity form baseline to simulator test. However, at stress offset (change from simulator to recovery) both psychological hardiness and physical fitness was positively related to positive PNS reactivity. This we interpret as a sign of a faster ability readjust to the new situation, which during recovery is more or less stress-free. This better ability to recuperate quickly and reset after stress might be a critical strength in an operational police setting, as one situation is often followed by a new situation that might demand entirely other resources and solutions. This activation pattern of lower PNS activity at stress onset and higher PNS activity at stress offset in line with Dienstebiers (1989) notion of the timing of arousal mentioned above (Gal & Lazarus, 1975). The effect of two stress conditions were also significant. The group exposed for the High Stress precondition exhibited lower change in parasympathetic reactivity compared to the Low Stress group. This shows that the prestress manipulation not only had an effect on the subjective self-reported feeling of stress but also on the objectively measured parasympathetic activation pattern.

Our finding of physical fitness to be predictive of higher PNS activity and hence faster arousal decline in the recovery phase in the High -Stress condition corresponds to previous studies linking physical fitness to lower cardiovascular stress reactivity and speedier recovery in response to psychological stress (Forcier, et al., 2006; Jackson & Dishman, 2006).That the level of physical fitness is predictive of the stress response in a more or less non-physical high-stress situation fits with the Cross-Stressor Adaption Hypothesis which emphasise that the reduced physiological reaction achieved through physical exercise is also transferred to non-exercise-related stressors (Klaperski, et al., 2014; Sothmann, et al., 1996). However looking at the correlations (table 3) and the follow up explorations of group differences (Figure 2) it seems that physical fitness do not to have the same influence in the Low-Stress condition as in the High-Stress condition. This is especially interesting as it might suggest that psychical fitness contributes more as a resilience factor in acute stress scenarios when the stress is substantially high, and the individuals' resources are more depleted. Those who do not often experience acute stress will thus be less aware of their needed physical fitness level to perform. This finding might also explain some of the inconsistencies in the literature regarding the size of the association between physical fitness and cardiovascular response, where some studies show more direct and large effects of physical fitness on cardiovascular stress responses, while others only find small to non-significant effects (Forcier, et al., 2006; Jackson & Dishman, 2006). These different findings may indeed be a result of the method of stress induction and also the magnitude of the stressor used in the studies.

All in all, psychological hardiness, physical fitness and condition explained about 32% of the observed variation in change of parasympathetic from the simulator to recovery. While this is a substantial contribution it still leaves a large part of the variance unexplained. Various genetic factors do influence HRV. One study by Singh and colleagues (Singh, Larson, O'Donnell, & Levy, 2001) estimated that between 13- 23 % of the variation in HRV could be accounted for by genetic factors. Genetic factors also contribute to both psychological resiliency and physical fitness, so some of the variations probably overlap, but also environmental factors contribute substantially (Horsburgh, Schermer, Veselka, & Vernon, 2009; Miyamoto-Mikami, et al., 2018; Perusse, et al., 1987).

The results of this study must be interpreted in light of some limitations. The use of a relatively small convenience sample may reduce the generalizability of the findings. While the participants where police students with one year practice and 1,5 year studies behind them, they might not react in the same way to stress as more experienced police officers. There might also be a self-selection bias as the students knew before they volunteered they would be tested for physical fitness using a $\dot{V}O_{2max}$ test. This may have prevented the students with lower self-esteem on physical tasks to volunteer. Another limitation is the relatively low Cronbach’s alpha found for the challenge dimension of hardiness (.616). This could limit the credibility of the results as regards this dimension, although it is not uncommon to find that the challenge scale has a notably lower reliability estimate than the other two dimensions (e.g., Heckman & Clay, 2005; Sigurd William Hystad, Eid, Johnsen, Laberg, & Bartone, 2010; Sandvik, Hansen, Johnsen, & Thayer, 2013). Our main aim was to not look at the subscales of hardiness, so they were not included in the regression analyses, but we still find it interesting to include them in the correlational analyses to also be able to explore possible effects the subscales.

In regard to the HRV baseline measure, it might be questionable if our measure indeed was of a true baseline. A baseline for the participants in both groups was measured before any other testing had begun and was seated and asked to relax, but they were all still anticipating an upcoming test. This anticipation means that they were mot probably not as relaxed as they would be if unaware of any upcoming test. However, none of the participants knew at the point of the baseline measure witch condition they were assigned to and there were no significant group differences in the RMSSD at baseline (see table 2). A group difference in RMSSD was first observed in the recovery phase. This difference between the groups observed at recovery suggests that stress level manipulation had an effect as intended.

A strength of this study is its use of a randomized experimental design and the use of well-established methods and apparatus for the measure of maximal aerobic capacity ($\dot{V}O_{2max}$), personality (DRS-15-R), and physiological stress activation (HRV). The use of a highly realistic simulator and a close to “real life” stress scenario heightens the ecological validity of the study.

4.1. Conclusions and Implications

There are a robust number of studies that have examined the link between physical fitness/activity and stress response, but to the best of our knowledge, this is the first study that has experimentally tested how parasympathetic control during acute stress in operational police settings is linked to individuals’ physical fitness and psychological hardiness. Overall the results suggest that psychological hardiness may be an important factor in how operational stress affects the individual in a police setting. Those high in hardiness seem to be better able to recuperate and reset after an stressful incident, something that can be vital in an operational context. Knowledge about who will show a more adaptive and resilient response pattern to stress can be beneficial in recruitment and selection to operational jobs.

Physical fitness is also a significant predictor of stress activation and recuperation in high-stress conditions. This highlights the importance of selection based on, and the importance of maintaining physical fitness for personnel in operational settings. This is not only to be able to complete physically demanding tasks and situations, but also to withstand non-physical, psychological stress. Physical fitness seems to be most important in high-stress situations where the individual's overall resources are more depleted.

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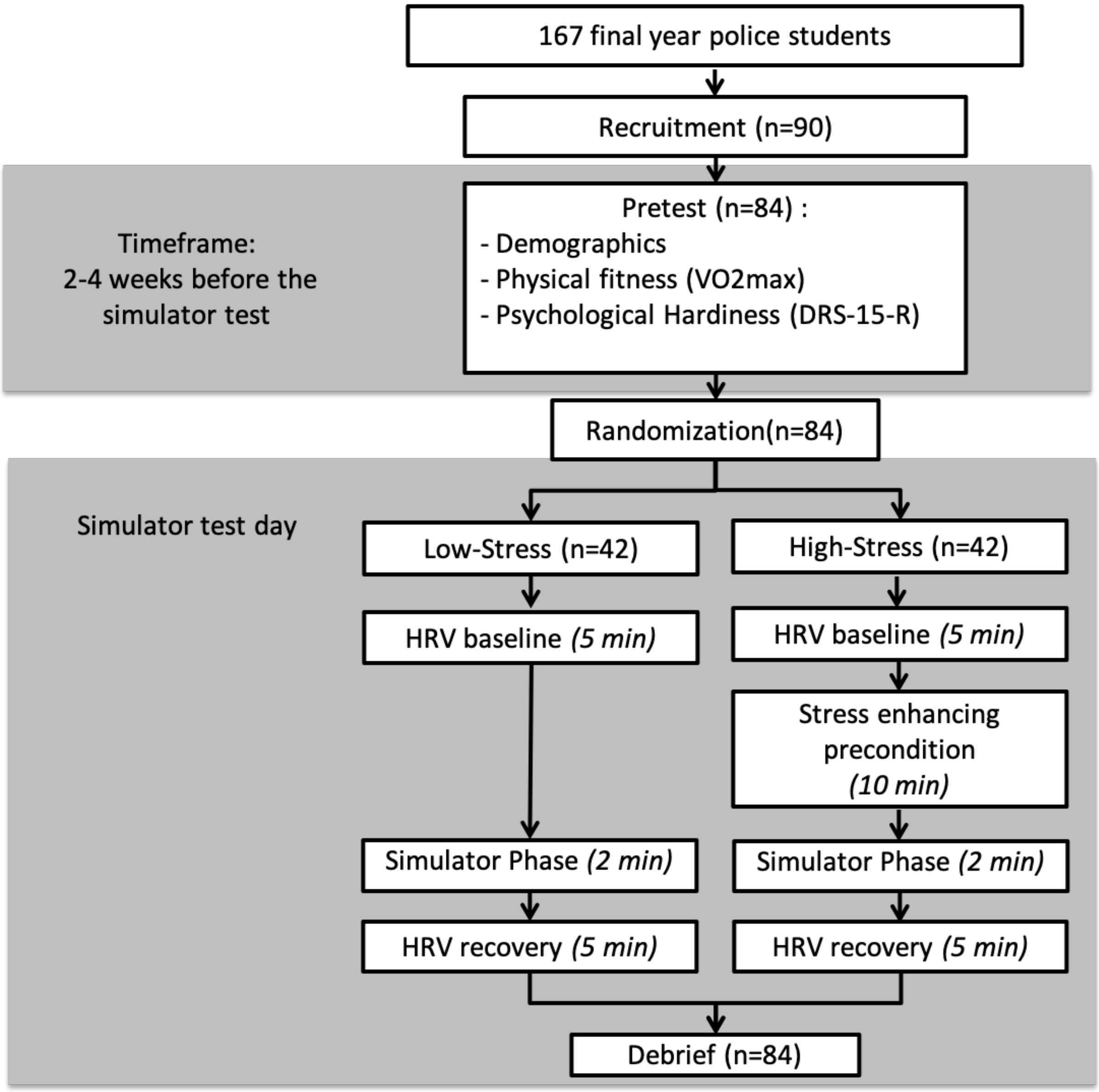

Figure 1. Study design and participant flow diagram

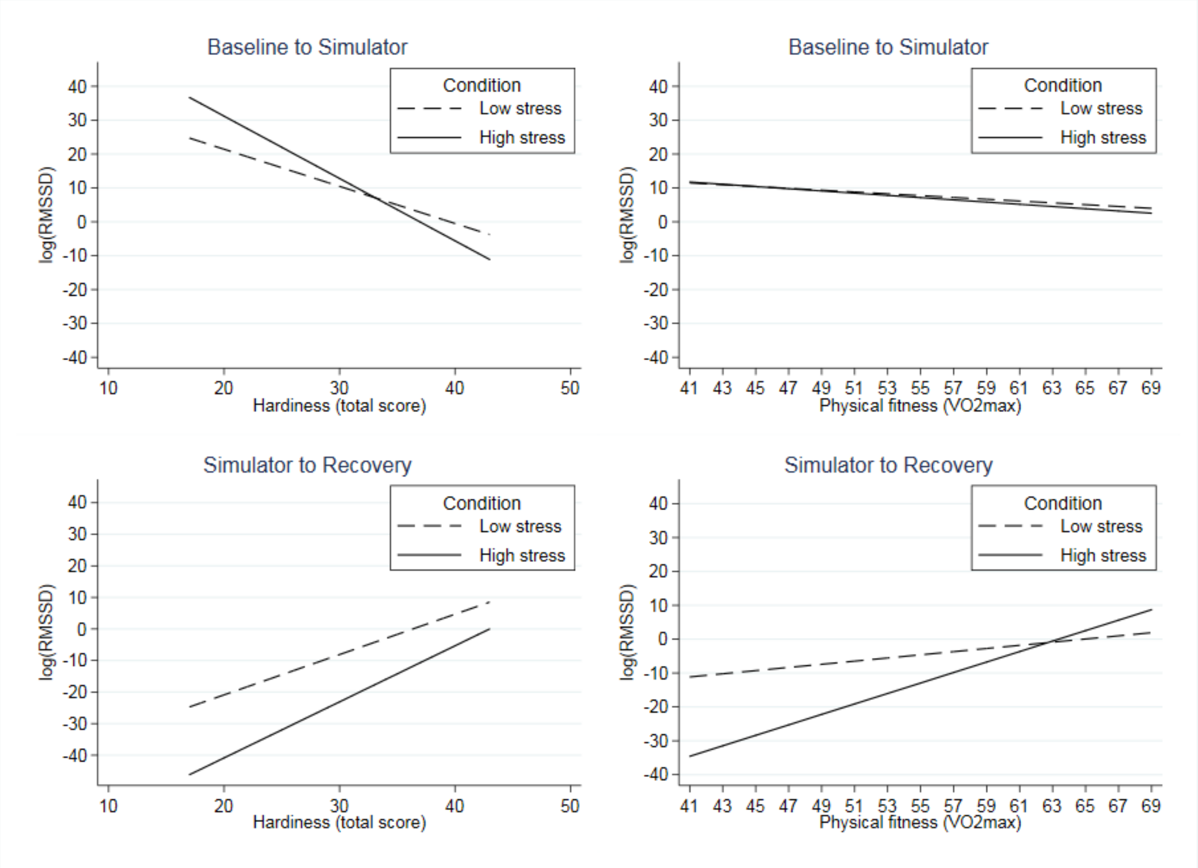

Figure 2. Exploratory analyses of group differences (low-stress vs. high-stress condition).

Table 1. Descriptive statistics

Descriptive Statistics

		N	Male	Female
	Total sample	84	42	42
	High stress group	42	22	20
	Low stress group	42	20	22

	Variables	Min	Max	Mean	SD
	Age (*years*)	22	33	24.25	2.15
	Age (Male)	22	27	23.81	1.38
	Age (Female)	22	33	24.69	2.66
	VO2max (*ml/kg/min*)	41.30	69.50	52.02	5.91
	VO2max (Male)	43.58	69.50	55.13	5.78
	VO2max (Female)	41.30	57.90	48.83	4.12
	VO2max*	1.62	1.84	1.71	0.05
DRS-15-R	Commitment (DRS-15-R)	5	15	11.33	2.17
	Control (DRS-15-R)	4	15	11.83	2.12
	Challenge (DRS-15-R)	4	14	9.10	2.35
	DRS-15-R (total score)	17	43	32.34	4.72
Heart rate (BPM)	BPM Baseline	52.20	161.33	87.45	15.42
	BPM Simulator	74.50	168.50	123.61	20.95
	BPM Recovery	54.80	119.40	87.52	15.32
rMSSD	rMSSD Baseline (*ms*)	12.78	684.74	80.67	98.36
	rMSSD Baseline*	1.11	2.84	1.75	0.33
	rMSSD Action (*ms*)	2.95	547.66	103.84	103.77
	rMSSD Action*	0.47	2.74	1.86	0.38
	rMSSD Recovery (*ms*)	4.09	419.32	58.65	60.93
	rMSSD Recovery*	0.61	2.62	1.61	0.38
	rMSSD Percent Change 1 (Baseline to Simulator)*	-65.16	61.23	7.55	21.85
	rMSSD Percent Change 2 (Simulator to Recovery)*	-63.08	66.76	-11.36	21.37

* Log transformed

Table 2. Group differences

Independent-sample t-test	Low-Stress (n=42) Mean (SD)	High-Stress (n=42) Mean (SD)	*t (df)*	*p*
Age (*years*)	24.43 (2.12)	24.07 (2.19)	*-.759 (82)*	*.450*
VO2max (*ml/kg/min*)	52.83 (6.55)	51.22 (5.18)	*-.1.245 (81)*	*.217*
DRS-15-R (total score)	32.10 (4.95)	32.58 (4.53)	.443 (77)	.659
Subjective stress before the simulator test (scale 1 - 10)	3.35 (1.76)	5.08 (1.92)	4.343 (83)	.000**
BPM Baseline	84.51 (11.87)	90.56 (18.07)	1.799 (80)	.076
BPM Simulator	114.99 (19.77)	132.65 (18.34)	4.239 (82)	.000**
BPM Recovery	79.75 (12.26)	95.67 (14.00)	5.551 (82)	.000**
RMSSD Baseline (*ms*)	73.51 (66.70)	88.02 (123.14)	.670 (81)	.505
RMSSD Action (*ms*)	108.78 (124.90)	98.66 (76.89)	-.445 (82)	.658
RMSSD Recovery (*ms*)	74.32 (73.30)	42.22 (39.01)	-2.488 (82)	.015*
RMSSD Percent Change (Baseline to Simulator)	6.15 (19.27)	8.98 (24.36)	.586 (81)	.559
RMSSD Percent Change (Simulator to Recovery)	-3.20 (17.74)	-19.91 (21.68)	-3.876 (82)	.000**

** p<.01, * p<.05 (two-tailed)

Table 3. Correlations

		RMSSD						Hardiness (DRS-15-R)		
		Baseline	Simulator	Recovery	Change 1	Change 2	VO2max	Commitment	Control	Challenge
High-Stress	RMSSD Baseline									
	RMSSD Simulator	.483**								
	RMSSD Recovery	.531**	.474**							
	RMSSD Change 1 (Baseline to Simulator)	-.440**	.554**	-.007						
	RMSSD Change 2 (Simulator to Recovery)	.134	-.436**	.552**	-.571**					
	VO2max	.252	.159	.519**	-.064	.345*				
	Commitment (DRS-15-R)	.039	-.336*	-.073	-.393*	.224	.018			
	Control (DRS-15-R)	-.027	-.121	.036	-.152	.245	.063	.314*		
	Challenge (DRS-15-R)	-.107	-.244	.011	-.116	.267	-.164	.202	.105	
	DRS-15-R (total score)	-.050	-.343*	-.035	-.324*	.341*	-.044	.736**	.650**	.668**
Low-Stress	RMSSD Baseline									
	RMSSD Simulator	.527**								
	RMSSD Recovery	.731**	.606**							
	RMSSD Change 1 (Baseline to Simulator)	-.282	.658**	.066						
	RMSSD Change 2 (Simulator to Recovery)	.094	-.597**	.252	-.724**					
	VO2max	.178	.121	.260	-.040	.076				
	Commitment (DRS-15-R)	.227	-.159	.236	-.416**	.487**	.106			
	Control (DRS-15-R)	.041	-.198	.148	-.272	.412**	-.013	.564**		
	Challenge (DRS-15-R)	.065	-.009	.181	-.074	.175	-.022	.420**	.170	
	DRS-15-R (total score)	.136	-.155	.244	-.317	.456**	.024	.837**	.751**	.713**

** p<.01, * p<.05

Table 3. Summary of the multiple regression analyses

	RMSSD Change - Baseline to Simulator				RMSSD Change - Simulator to Recovery			
	B	*SE B*	95% C.I.	β	*B*	*SE B*	95% C.I.	β
Block 1: main effects								
Condition: High stress	.10	4.85	[-9.58; 9.77]	—	-12.10**	3.78	[-19.62; -4.56]	—
Physical fitness (VO_{2max})	-0.28	0.40	[-1.07; 0.51]	-.08	0.89**	0.31	[0.27; 1.51]	.28
Hardiness	-1.43**	0.51	[-2.44; -0.41]	-.31	1.47***	0.40	[0.67; 2.27]	.36
R^2			.103				.319	
$F(3, 73)$			2.76*				11.44***	
Block 2: two-way interactions								
Condition * Physical fitness	-0.06	0.82	[-1.70; 1.58]	—	1.08	0.63	[-0.18; 2.34]	—
Condition * Hardiness	-0.74	1.04	[-2.81; 1.32]	—	0.50	0.80	[-1.09; 2.09]	—
ΔR^2			.01				.03	
$\Delta F(2, 71)$			0.26				1.63	

***P<.001 ** P<.01 *P<.05