THE RELATIONSHIP BETWEEN HEART RATE VARIABILITY, SELF-
PERCEPTION, EXERCISE, MOOD, AND SLEEP INDICES IN COLLEGIATE
WOMEN'S TRACK AND FIELD DURING A COMPETITIVE SEASON

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By

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Dedication

To my family and friends for all of your love, guidance, and support.
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Mahalo to my thesis committee: Dr. Nathan Murata, my advisor, Dr. Alayne Yates, Dr. John Rand, Dr. Coop DeRenne, and Hervé Collin. When the chips were down for me, you all stuck with me and I am most grateful for that.

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Abstract

This research examined in-season changes in physiological and psychological measures, and related them to training over time (4-months) in women's track and field during a competitive collegiate season. Fifteen female athletes between the ages of 18 and 24 years old participated. Each participant completed the Exercise Orientation Questionnaire (EOQ), where four questions were derived from the Self-Loathing Subscale (SLSS) questionnaire, the Epworth Sleepiness Scale (ESS) Questionnaire, the Profile of Mood States (POMS) Standard Form Questionnaire, and heart rate variability (HRV) testing protocols during each of their four testing sessions. Testing sessions included the application of a tilt table to measure the LF/HF ratio in female track and field athletes. A developmental and quasi-experimental research design with repeated measures was employed in this study. Data collection of the LF/HF ratio occurred across three plains (0 degrees, 70 degrees, and 0 degrees). The test results revealed that there were no significant differences in the following: (1) LF/HF ratio over the four trials due to the high amount of in-season training that they received over a period of 4-months; (2) comparison to the POMS and SLSS questionnaires as a covariate; and (3) comparing the ESS questionnaire as a covariate. In conclusion, the physiological stress from the tilt table testing did not seem to affect the participant's ability to adapt to physiological stress over the four trials, however, it can be noted that when using the ESS questionnaire as a covariate, data appear to be approaching significance.
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Chapter I

Introduction

The search for minimally invasive and limited disturbing indicators of training status in athletes, while trying to optimize training with the aim of improving physical performance, has always been of interest in sports medicine and physiology (Iellamo, Pigozzi, Spataro, Lucini, & Pagani, 2004). One method of evaluating the training status of athletes is by monitoring their autonomic nervous system (ANS) through the use of heart rate variability (HRV) analysis (Task Force of the European Society of Cardiology & the North American Society of Pacing & Electrophysiology, 1996). Heart Rate Variability regulates the sinoatrial node, which is also known as the natural pacemaker of the heart through the sympathetic and parasympathetic branches of the ANS (Anonymous, 2005). Power spectral analysis of beat-to-beat variability is now used to estimate autonomic function. High frequency (HF; 0.15 - 0.45 Hz) modulation of heart rate (HR) reflects vagal activity (parasympathetic activity), whereas low frequency (LF; 0.03 - 0.15 Hz) modulation seems to reflect both vagal and sympathetic activity (Burr, 2007; Iellamo, et al., 2004; Pichot, Roche, Gaspoz, Enjolras, Antoniadis, Minini, Costes, Busso, Lacour, & Barthélémy, 2000; Task Force of the European Society, 1996). The ratio of low to high frequency (LF/HF Ratio) is often used as an index of sympathetic/parasympathetic balance.

Heart rate variability will vary in response to different stimuli and many researchers have used tilt table testing (orthostatic duress) to evaluate health of the autonomic system response to this type of stress. In comparison to supine rest, increased LF has been observed during tilt, standing, and mental stress (Task Force of the European
Society, 1996). Recently, Uusitalo, Uusitalo, and Rusko (1999) reported that heavy training could increase cardiac sympathetic modulation during supine rest and attenuated biphasic baroreflex-mediated responses to orthostatic challenge. They concluded that the overtraining state (reduction in performance and a decline in physiological function) seemed to be related to the tendency of heart rate variability to decrease in the standing position as a sign of pronounced vagal withdrawal and in some cases decreased sympathetic excitability (Uusitalo, et al., 1999). At least two other studies have reported a decrease in heart rate variability with overtraining (Iellamo, Legramante, Pigozzi, Spataro, Norbiato, Lucini, & Pagani, 2002; Mourot, Bouhaddi, Perrey, Cappelle, Henri, Wolf, Rouillon, & Regnard, 2004). Mourot, et al. (2004) reported that when analyzing variables associated with heart rate variability, the shape of Poincare plots allowed for distinction between control, trained and overtrained athletes. Pichot, et al. (2000) studied seven male middle-distance runners who were ranked at the national level in France and suggested that by performing a nocturnal heart rate variability measurement, which is recognized to have a successful reproducibility, overtraining status may be identified.

Bosquet, Papelier, Léger, and Legros (2003) suggested that heart rate variability during sleep did not seem to be a valid marker of overtraining in nine (six runners and three tri-athletes) moderately to well-trained male endurance athletes. However, they stated that before concluding that heart rate variability is not a useful tool in diagnosing overtraining syndrome, longitudinal studies are needed to determine if spontaneously developed overtraining results in changes in heart rate variability during sleep may occur. Recently, Waldeck and Lambert (2003) assessed the repeatability of HR during sleep to determine whether this measurement had sufficient precision to use as a marker of
training status and found that an important factor to consider before changes in HR can be interpreted with any degree of accuracy is to know the intrinsic day-to-day variations in HR during sleep.

**Statement of the Problem**

Although autonomic function has been studied in conjunction with overtraining, primarily in men, to date, changes in heart rate variability due to the stress of training and competing during a collegiate competitive season has not been studied. Thus, there is a paucity of research investigating the interaction of women track and field athletes during a competitive collegiate season. Tracking changes in heart rate variability, sleep patterns, changes in mood, and performance in relation to the increases and decreases of training volume (e.g., distance a runner ran per day) may give insight to normal and abnormal physiological and psychological responses to training and competition. Collection of such data may lead to the future development of an instrument sensitive to the detection of overtraining.

**Purpose of the Study**

The purpose of this research study was to examine in-seasonal changes in selected physiological (HRV) and psychological (Profile of Mood States [POMS] Standard Form questionnaire, Self-Loathing Subscale [SLSS] questionnaire, where four SLSS questions were derived from the Exercise Orientation Questionnaire [EOQ], and Epworth Sleepiness Scale [ESS] questionnaire) measures, and relate them to training over time (4-months) in female collegiate track and field athletes during a competitive collegiate season. No attempt was made to influence the athlete’s training programs during the course of this research study. The data collected may help to tailor training protocols by
establishing a relationship between minimally invasive methods (HRV, self-perception, compulsive exercising, mood, and sleep) with the training status and performance of athletes. It may be possible to detect the onset of overtraining by using these invasive methods.

**Null Research Statements**

The following null research statements were addressed:

1. There will be no difference between the amount of high in-seasonal training that the collegiate track and field women receive over a period of 4-months (competitive training and competitions) and their ability to respond to stress.

2. There will be no difference between the amount of high in-seasonal training that the collegiate track and field women receive over a period of 4-months (competitive training and competitions) and their self-perception, tendency to develop compulsive exercising behavior, mood disturbance, and sleepiness level.

**Limitations**

The limitations of this research study were: the number of participants who volunteered for the study, the participant’s training regimen (which was designed by their event specific track and field coaches and/or team athletic trainer), injuries due to exercise training or other daily activities, illness, the extent of the participants’ athletic experience in track and field, the participants’ current level of exercise, the participants’ current level of physical fitness, the participant’s motivation to participate in the research study’s activities, and the participants’ behavior during the data collection.
Delimitations

The delimitations of this research study include: the use of the University of Hawai‘i at Mānoa’s Women’s Track and Field team (during in-season training and competitions) that met the qualified age range of 18 through 24.

Operational Definitions

1. **Aortic Reflex** - “A reflex concerned with maintaining normal systemic blood pressure (Tortora & Grabowski, 2000, p. G-3).”

2. **Autonomic Nervous System (ANS)** - “Visceral sensory (afferent) and motor (efferent) neurons, both sympathetic and parasympathetic. Motor neurons transmit nerve impulses from the central nervous system to smooth muscle, cardiac muscle, and glands; so named because this portion of the nervous system was thought to be self-governing or spontaneous (Tortora & Grabowski, 2000, p. G-5).” A portion of the nervous system that controls the actions of visceral organs. It plays an important role in maintaining the constancy of the body’s internal environment.

3. **Baroreceptor** - “Nerve cell capable of responding to changes in blood, air, or fluid pressure. Also called a pressoreceptor (Tortora & Grabowski, 2000, p. G-5).” In the walls of some arteries and veins that monitor blood pressure.

4. **Biomarker** - “A specific physical trait used to measure or indicate the effects or progress of a disease or condition (American Heritage College Dictionary, 1997, p. 139).”

5. **Carotid Sinus Reflex** - “A reflex concerned with maintaining normal blood pressure in the brain (Tortora & Grabowski, 2000, p. G-7).”
6. **Central Nervous System (CNS)**- "That portion of the nervous system that consists of the brain and spinal cord (Tortora & Grabowski, 2000, p. G-7)."

7. **Electrocardiogram (ECG or EKG)**- "A recording of the electrical changes that accompany the cardiac cycle that can be detected at the surface of the body; may be resting, stress, or ambulatory (Tortora & Grabowski, 2000, p. G-12)."

8. **Epworth Sleepiness Scale (ESS) Questionnaire**- An effective instrument used to measure excessive sleepiness or excessive daytime sleepiness. The ESS differentiates between average sleep and significant issues with sleepiness that require intervention. The client self-rates on how likely it is that he/she would doze in eight different situations. Scoring of the answers is 0-3, with 0 being ‘would never doze’ and 3 being ‘high chance of dozing’. A sum of 9 or more from the eight individual scores reflects ‘very sleepy and should seek medical advice’ (Johns, 1991)."

9. **Exercise Orientation Questionnaire (EOQ)**- Constructed specifically for use with individuals who exercise, including athletes, and has been found to be a reliable and valid measure of exercise orientation for a non-clinical sample. (Yates, Edman, Crago, Crowell, & Zimmerman, 1998)

10. **Heart Rate Variability (HRV)**- "Reflects the continuous oscillation of the R-R intervals around its mean value, providing non-invasive data about the autonomic regulation of heart rate in real-life conditions (Mourot, et al., 2004, p. 10)."

11. **Hertz (Hz)**- "A unit of frequency equal to one cycle per second (American Heritage College Dictionary, 1997, p. 637)."
12. **High Frequency (HF)**- “A radio frequency in the range between 3 and 30 megahertz (American Heritage College Dictionary, 1997, p. 641).” For the purposes of this research study, HF modulation (0.15-0.45 Hz) will reflect vagal activity (parasympathetic activity) (Iellamo, et al., 2004; Pichot, et al., 2000; Task Force of the European Society, 1996).

13. **Low Frequency (LF)**- “A radio frequency in the range from 30 to 300 kilohertz (American Heritage College Dictionary, 1997, p. 804).” For the purposes of this research study, LF modulation (0.03 - 0.15 Hz) modulation seems to reflect both vagal and sympathetic activity (Iellamo, et al., 2004; Pichot, et al., 2000; Task Force of the European Society, 1996).

14. **Low Frequency/High Frequency Ratio (LF/HF ratio)**- The ratio of low to high frequency (LF/HF) is often used as an index of parasympathetic-sympathetic balance. (Iellamo, et al., 2004; Pichot, et al., 2000; Task Force of the European Society, 1996).

15. **Maximal Oxygen Uptake (V\textsubscript{O\textsubscript{2}}\text{max})**- “The maximal capacity for oxygen consumption by the body during maximal exertion. It is also known as aerobic power, maximal oxygen intake, maximal oxygen consumption, and cardiorespiratory endurance capacity (Wilmore & Costill, 1994, p. 697).”

16. **Motor Neuron**- “A neuron that conducts nerve impulses from the brain and spinal cord to effectors that may be either muscles or glands. Also called an efferent neuron (Tortora & Grabowski, 2000, p. G-24).”

17. **Parasympathetic**- “Of relating to, or affecting the parasympathetic nervous system (American Heritage College Dictionary, 1997, p. 991).”
18. **Parasympathetic Nervous System**: "The part of the autonomic nervous system originating in the brain stem and the lower part of the spinal cord that in general inhibits or opposes the physiological effects of the sympathetic nervous system, as in tending to slow the heart and dilate blood vessels (American Heritage College Dictionary, 1997, p. 991)." Parasympathetic impulses tend to inhibit the activation of an organ (i.e., slows heart rate).

19. **Profile of Mood States (POMS) Standard Form Questionnaire**: A questionnaire composed of sixty-five descriptors and uses a Likert scale to evaluate mood. The POMS has been used to monitor mood changes consistent with increases in training load and may be a sensitive instrument for monitoring overtraining. (Hawley & Schoene, 2003; Hedelin, Wiklund, Bjerle, & Henriksson-Larsen, 2000; Lehmann, Foster, & Keul, 1993)

20. **Self-Loathing Subscale (SLSS) Questionnaire**: A questionnaire of the EOQ, which is composed of eight questions about exercise and self-perception, has been shown to differentiate clinical from non-clinical groups, while other sub-scales did not. The SLSS could provide a theoretical bridge between compulsive athleticism and eating disorders. (Yates, Edman, Crago, & Crowell, 2001)


22. **Sympathetic Nervous System**: "The part of the autonomic nervous system originating in the thoracic and lumbar regions of the spinal cord that inhibits or opposes the physiological effects of the parasympathetic nervous system, as in speeding up the heart and contracting blood vessels (American Heritage College Dictionary, 1997, p. 1374)."
Dictionary, 1997, p. 1375).” Sympathetic portion of the autonomic nervous system tends to activate an organ (i.e., increase heart rate).


24. **Systemic**- “Affecting the whole body; generalized (Tortora & Grabowski, 2000, p. G-37).”

25. **Vagal**- “Of or relating to the vagus nerve (American Heritage College Dictionary, 1997, p. 1488).”


28. **Visceral**- “Pertaining to the organs or to the covering of an organ (Tortora & Grabowski, 2000, p. G-41).”

29. **VO₂max**- see Maximal Oxygen Uptake (VO₂max).
Chapter II

Method

Participants and Site

Approval to conduct this research study was sought and obtained from the University of Hawai‘i at Mānoa’s Office of Research Service’s Committee on Human Studies (CHS) (Appendix A) and the federally mandated Institutional Review Board (IRB) for the University of Hawai‘i (UH) system. The purpose of this office and committee is to ensure the rights and welfare of the participants in this research study.

Seventeen female (n=17) collegiate track and field athletes were recruited from the University of Hawai‘i at Mānoa’s Women’s Track and Field team. The participants competed in the following track and field events: distance runner: 3000m run, 5000m run, 10,000m run; middle distance runner: 800m run, 1500m run; heptathlete: 100m hurdles, high jump, shot put throw, 200m run, long jump, javelin throw, 800m run; sprinter/hurdler: 100m run, 200m run, 400m run, 110m high hurdles, 300m hurdles; jumper: high jump, long jump, triple jump, pole vault; and thrower: shot put throw, discus throw, hammer throw, javelin throw. The participants’ involvement in this research study were entirely voluntary. All information collected from the participants was kept strictly confidential and individual data were not released to their coaches. Each participant was assigned a randomized number to protect her confidentiality.

The recruitment of the participants was conducted through an informal meeting with the athletes, teams’ staff (coaches and athletic trainer) and a professor from the Kinesiology and Leisure Sciences Department. The in-season training program was never altered during this study. All participants were informed of the purpose and possible risks
associated with this study. Participants completed all necessary packet forms. Each packet included an introductory letter (Appendix B), a written Informed Consent form (Appendix C), a Medical History Questionnaire (Appendix D), and a Physical Activity Readiness Questionnaire (PAR-Q) (Appendix E) in order to eliminate individuals with serious health conditions prior to the initial test visit. The participants were asked to maintain their normal diet and to keep a distributed weekly recorded training log (Appendix F), throughout the research study. No attempt was made to manipulate the participant’s training program for the purposes of this research study.

Research Design

This research study involved both a developmental research design and quasi-experimental research design with repeated measures. Thomas and Nelson (2001) describe developmental research studies as “changes in behavior across years (p. 277)”, using the same participants over a period of time. This type of research design consists of longitudinal and cross-sectional studies where “researchers investigate the interaction of growth and maturation and of learning and performance variables” (Thomas & Nelson, 2001, p. 277). Heffner (2004), Wilmore and Costill (1994), and Pedhazur and Pedhamr Schmelkin (1991) state that longitudinal studies assess changes, by involving repeated observations of the same items, over an extended period of time by looking at the same groups of participants for months, years, or even decades. Longitudinal studies are powerful because it tracks changes in behavior over time with the same people, however, it is a very time consuming process (Heffner, 2004; Thomas & Nelson, 2001).

The second type of design involves a quasi-experimental research design. Thomas, Nelson, and Silverman (2005) stated that “a quasi-experimental design is to “fit”
the design to settings more like the real world while still controlling as many of the threats to internal validity. Within this type of research, the use of randomization to control threats to internal validity is difficult (p. 335). More specifically, this study utilized intact groups; albeit collegiate female track and field members.

Since all participants received treatment, and no randomization occurred, the quasi-experimental design was used to measure the effects of intervention. Clearly, threats to internal and external validity can occur; however, the real-world setting in which this study took place made the quasi-experimental design the appropriate choice.

One problem with longitudinal studies is not knowing whether the sample characteristics remain the same when participants leave the study (e.g., school districts being rezoned, athletes move away, mortality rate due to illness, socioeconomic levels change when more affluent participants relocate). Thomas and Nelson (2001) state another problem, includes participants become increasingly familiar with the test items, and that the items may cause changes in the participant’s behavior. Some participants may want to increase their knowledge on the item or topic being studied and seek information about it, therefore changing their knowledge, attitude, and behavior. However, this gain of knowledge is the result of having been exposed to the test earlier and might not have occurred without that exposure.

Although problems exist in longitudinal studies, this type of study seems to be the only means available to study human development, therefore, it is necessary and a very important type of research design. Longitudinal studies seem to rule a variety of methodological problems (Thomas & Nelson, 2001). For instance, unrepresentative scores, also known as outliers, occur in all types of research but are particularly
problematic in developmental research, especially when studying children and senior citizens due to their shorter attention spans, being distracted easily, and lack of motivation to do the task. They also stated that unclear semantics, which is the selection of words to use in explaining a task to various age groups, is a formidable challenge. The standard rule in good research is to give identical instructions to all the participants; however, there is a lack of reliability and problems with statistics. Testing effects may also be assessed, though they may be complicated to differentiate from maturation. Selection biases also seem to be unvarying as the same participants are utilized at each examination.

Instrumentation

Data were collected using the following instruments: the POMS Standard Form questionnaire was used to evaluate the participant’s mood (Total Mood Disturbance [TMD]). The EOQ was provided where analysis of the SLSS questionnaire was used. More specifically, four questions: 1. I disliked my body before I began to exercise., 3. I am dissatisfied with my performance., 5. I hate my body when it won’t do what I want., and 7. If I don’t reach my exercise goals, I feel like a failure., were analyzed. The ESS questionnaire was used to determine how sleepy the participant was throughout the day. An electric tilt table was used to carry out the 70° head-up tilt. The CARDIO-CARD version 4.12 software (Nasiff Associates Inc., Brewton, NY, USA) program collected the electrocardiogram (ECG) data while the participant was on the tilt table. The participant’s R-R data was saved for later analysis. The HRV Data Filter (created by Christopher Stickley, M.A., A.T.C., University of Hawai‘i at Mānoa) was developed and used to identify and eliminate extraneous information (ectopic beats- abnormally large data
points and negative data points) from the raw R-R data. Data reduction following this
criteria was accomplished using a Microsoft Excel spreadsheet utilizing macro codes
created in Microsoft Visual Basic. After all ectopic beats were removed, data were
inserted into the Time Chop Off (created by Hervé Collin, M.S., University of Hawai‘i at
Mānoa and Kapi‘olani Community College). Since markers were not available with the
device measuring the R-R intervals, the following method was used. Measurements were
taken for a period of 30-minutes: 20-minutes in the supine position at 0°, 5-minutes in a
head-up tilted position at 70°, and 5-minutes tilted back down to a supine position at 0°.
Only the last 5-minutes of the first supine position were considered. Hence, the last three
conditions were extracted: the last 5-minutes of the first 20-minutes of measurement at
0°, the tilted position at 70°, and the last horizontal position at 0°. Since the data points
refer to the time between the two consecutive R intervals in the PQRST events of the
ECG, the sum N of all R-R intervals correspond to the whole 30-minutes of
measurements. This value in milliseconds (ms) was divided up into four parts. The first
condition (supine at 0°) was extracted by considering all data points between N/4 and
N/2, the second condition (tilted up at 70°) was extracted by considering all data points
between N/2 and 3N/4, and the last condition (tilted back down to 0°) was extracted by
considering the last data points between 3N/4 and N. This was developed with a
Microsoft Excel Spreadsheet and used to separate each 5-minute R-R interval data
collected during supine rests at 0° and during a 70° head-up tilt.

Data were separated into “Pre-Tilt Data” (5-minutes prior to being tilted), “Tilt
Data” (5-minutes at a 70° head-up tilt), and “Post Tilt Data” (5-minutes after tilt) prior to
inserting the data into the Heart Rate Variability Analysis software program. The Heart
Rate Variability Software version 1.1- Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland (Niskanen, Tarvainen, Ranta-aho, & Karjalainen, 2002) was used to analyze each participant’s R-R interval data which determined their LF, HF, and LF/HF Ratio values. Details of the Heart Rate Variability Analysis software program were published by Niskanen, Tarvainen, Ranta-aho, and Karjalainen (2002).

**Dependent Variable.** The dependent variables were the HRV data, POMS Standard Form questionnaire (Appendix G), SLSS questionnaire (Appendix H) where four SLSS questions were derived from the EOQ (Appendix I) which was given to the participants, and the ESS questionnaire (Appendix J).

**Independent Variables.** The independent variable was the effect of the 70° tilt table test due to each participant’s training volume. Heart rate variability was measured for 20-minutes in the lying position at 0°, during a 70° head-up tilt table test for 5-minutes, and back down to the lying position at 0° for an additional 5-minutes. Participants were monitored for symptoms of syncope during the tilt table test.

**Training of Data Collector.** This research study utilized one data collector to collect the HRV data, POMS Standard Form questionnaire, SLSS questionnaire where four SLSS questions were derived from the EOQ which was given to the participants, and ESS questionnaire. A training session was conducted with the assistance of another Kinesiology of Leisure Science graduate student, who was familiar with the Heart Rate Variability Analysis Software Program, and an undergraduate student at the University of Hawai‘i at Mānoa, to familiarize the data collector with the design of the research study and its’ testing protocol. The data collector was instructed to issue the same directions to
the participants and to not offer any assistance or encouragement. The data collectors' directions consisted of:

"Please fill out the Exercise Orientation Questionnaire, Profile of Mood States questionnaire, and Epworth Sleepiness Scale questionnaire. If you have any questions about the questionnaires please feel free to ask me. When you are finished, I will prep you and hook you up to the ECG machine. I will place two electrodes on your chest, one on each wrist, and one on the side of your chest. You will lie on your back for a total of 30-minutes. Twenty minutes at 0°, 5-minutes at 70°, and 5-minutes back down at 0°. If at any time you feel dizzy or faint and cannot continue with the testing, please let me know and I will stop the testing. Do you have any questions?"

Data Collection

Data were collected following the start of the women’s track and field season, twice mid-season, and 2-weeks prior to the women’s Western Athletic Conference (WAC) Track and Field Championship meet. All tests were performed in the Human Performance Laboratory in the Stan Sheriff Center at the University of Hawai‘i at Mānoa. The participants arrived for testing between the hours of 6:00 a.m.-12:00 p.m. All participants were tested at the same time of day during the course of the track and field season as described above. Participants were instructed to refrain from eating, training, caffeine, alcohol, smoking, or the use of other substances, on the morning of their scheduled test. The participants were allowed to drink water with their prescribed
medication as instructed by their physician. The research team accommodated the participant’s schedule so that they were tested soon after waking.

At the initial test visit, each participant completed an EOQ (Yates, et al., 1998), which includes the four questions from the SLSS questionnaire (Yates, et al., 2001), the POMS Standard Form questionnaire (Grove & Prapavessis, 1992), and the ESS questionnaire (Johns, 1991). Yates, et al. (1998) developed the Exercise Orientation Questionnaire which was constructed specifically for use with individuals who exercise, including athletes, and has been found to be a reliable and valid measure of exercise orientation for a non-clinical sample (Yates, et al., 1998). The Self-Loathing Subscale questionnaire of the EOQ, which is composed of eight questions about exercise and self-perception, has been shown to differentiate clinical from non-clinical groups, while other sub-scales did not (Yates, et al., 2001). The SLSS could provide a theoretical bridge between compulsive athleticism and eating disorders (Yates, et al., 2001). The POMS Standard Form questionnaire is composed of sixty-five descriptors and uses a Likert scale to evaluate mood. The POMS has been used to monitor mood changes consistent with increases in training load and may be a sensitive instrument for monitoring overtraining (Hawley & Schoene, 2003; Hedelin, Wiklund, et al., 2000; Lehmann et al., 1993). The participant’s height (cm) and weight (kg) were also taken at the beginning of each testing session. Measurements were collected by a female member of the research team.

Heart rate variability was measured for 20-minutes in the supine position at 0°, during a 70° tilt table test for 5-minutes, and back down to the supine position at 0° for an additional 5-minutes. Participants were monitored for symptoms of syncope during the tilt table test. Heart rate variability was measured using a CARDIO-CARD version 4.12
software program and the participants were prepped by a female member of the research team. Preparation of electrode placement included a thorough cleaning of the placement area with an alcohol prep. One electrode was placed on the palmar side of the wrist just above the wrist crease between the radial and ulnar styloid processes bilaterally. One electrode was placed inferior to the 10th rib in the mid-clavicular line bilaterally. One lead V6 electrode was placed at the 5th intercostal space on the right mid-axillary line. Leads were attached to the electrodes and the participants were asked to lay supine on the tilt table and to refrain from moving. Participants were asked to breathe at a normal rate while the researcher started data collection and monitored the participant for abnormalities. The participant remained supine for 1200s (20-minutes) at 0°, then tilted to 70° for 300s (5-minutes), then back down to 0° in the supine position for an additional 300s (5-minutes). Total time on the tilt table was 1800s (30-minutes) of data collection. Once recording was completed the electrodes were removed by a female member of the research team.

The investigator examined the data and saved it as an ASCII text file, on the computer, so that the recordings could be imported to the HRV Analysis program for later analysis (Niskanen, et al., 2002). The data were examined and ectopic beats were removed by using the HRV Data Filter (created by Christopher Stickley). After the data were examined and all ectopic beats were removed, data were inserted into the Time Chop Off (created by Hervé Collin). This was developed and used to separate each 5-minute R-R interval data collected during supine rests at 0° and during a 70° head-up tilt. The data were separated into “Pre-Tilt Data” (5-minutes at 0° prior to being tilted), “Tilt Data” (5-minutes at a 70° head-up tilt), and “Post Tilt Data” (5-minutes at 0° after tilt)
prior to inserting the data into the Heart Rate Variability Analysis software program to be analyzed. Data analyses were conducted for the following: LF, HF, and LF/HF Ratio.

Participants completed the EOQ (which included four SLSS questions), the POMS Standard Form questionnaire, the ESS questionnaire, and the HRV testing protocols pre-season, twice mid-season, and 2-weeks prior to the women’s WAC Track and Field Championships. The total time involved per participant during each testing session was approximately 1-hour.

Data Analysis

Data were analyzed using SAS version 9.1.3 statistical computer software for Windows (SAS Institute Inc., Cary, NC). Descriptive statistics were used in evaluating the data and to calculate the difference in the means and standard deviations of the participants’ mean Raw Data for POMS, SLSS where four questions were derived from the EOQ, ESS, and the participants’ demographic information. Mixed model ANOVA was used to determine statistical significance. Statistical significance (alpha level: α) was set at $p < 0.05$. ANCOVA was used to include R-R interval data and questionnaire data as covariates. The Tukey-Kramer method was used for pair wise comparisons.
Chapter III

Results

The purpose of this research study was to examine in-seasonal changes in selected physiological (HRV) and psychological (POMS Standard Form questionnaire, SLSS questionnaire where four SLSS questions were derived from the EOQ, and ESS questionnaire) measures, and relate them to training over time (4-months) in women collegiate track and field athletes during a competitive collegiate season.

All of the participants completed the selected physiological and psychological measures during the track and field season. Trials 1-4 were used to determine whether or not there was a significant difference in the participants’ HRV, POMS Standard Form questionnaire, SLSS questionnaire (where four questions were derived from the EOQ which was given to each participant), and ESS questionnaire. Physiological and psychological data were collected on four separate occasions for each participant.

Descriptive Statistics

Seventeen (n=17) female participants from the University of Hawai‘i at Mānoa’s Women’s Track and Field team gave their consent to participate in this research study. The amount of participants was not under the control of this research study, as the participants’ involvement was voluntary. Two participants dropped out due to attrition bringing the total number of participants to 15 (n=15). All of the participants’ collected questionnaire scores are shown in the Raw Data Tables in Appendix K (ESS questionnaire), Appendix L (POMS Standard Form questionnaire), and Appendix M (SLSS questionnaire). Mean values and standard deviations for the participants’
demographic information are presented in Table 1. Raw Data Table in Appendix N (Participant’s Demographics).

Table 1

*Participant's Demographics (Mean ± SD)*

<table>
<thead>
<tr>
<th>Female Participants' Demographics</th>
<th>n</th>
<th>(Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>15</td>
<td>19.93±1.16</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>15</td>
<td>168.79±8.18</td>
</tr>
<tr>
<td>Weight (kg)- Trial 1</td>
<td>15</td>
<td>61.11±14.72</td>
</tr>
<tr>
<td>Weight (kg)- Trial 2</td>
<td>15</td>
<td>61.12±14.92</td>
</tr>
<tr>
<td>Weight (kg)- Trial 3</td>
<td>15</td>
<td>61.44±14.53</td>
</tr>
<tr>
<td>Weight (kg)- Trial 4</td>
<td>15</td>
<td>61.06±13.82</td>
</tr>
</tbody>
</table>

*ANOVA and ANCOVA Statistics*

All of the participant’s data with LF/HF Ratio over the four Trials and where the ESS questionnaire, POMS Standard Form questionnaire, and SLSS questionnaire (where four questions were derived from the EOQ) were used as covariates are shown in Table 2 (Difference in LF/HF Ratio over the 4 Trials and compared to the ESS, POMS, and SLSS as covariates), and Table 3 (Profile of Mood States over the 4 Trials where the Trial 1-4 R-R interval readings were included as covariates).

*Difference in LF/HF Ratio (Tilt Data - Pre-Tilt Data) over the 4 Trials*

The amount of training over time (4-months of competitive training and competition) did not significantly affect the participant’s LF/HF Ratio over Trials 1-4.
when using the ANOVA analysis, \( F = 1.06; \) d.f. = 22; \( P = 0.3876 \). The amount of training over the four Trials does not seem to affect the participant's ability to respond to physiological stress. Raw Data Table in Appendix O (Absolute Difference in LF/HF Ratio (%) over Trials 1-4).

### Difference in LF/HF Ratio (Tilt Data – Pre-Tilt Data) over the 4 Trials and compared to the ESS, POMS, and SLSS (questionnaires were used as covariates)

The amount of training over time (4-months of competitive training and competition) does not seem to affect the participant's Trials 1-4 results (LF/HF Ratio) when using the ESS questionnaire, POMS Standard Form questionnaire, and SLSS questionnaire (where four questions were derived from the EOQ questionnaire that was given to the participants) results as a covariate factor in the ANCOVA analysis (based on all \( p \) values < 0.05). The ESS questionnaire, which was used as a covariate with the Trials over 4-months, showed an approach towards a significant interaction \( (F = 2.34; \) d.f. = 18; \( P = 0.1071 \)). These results suggest that there is no difference between ESS questionnaire responses and R-R interval, with lower ESS scores at higher R-R interval readings. The POMS questionnaire results \( (F = 1.23; \) d.f. = 18; \( P = 0.3268 \)) and the SLSS questionnaire results \( (F = 1.16; \) d.f. = 18; \( P = 0.3527 \)) show that the amount of training over the four Trials did not significantly affect the participant's ability to respond to physiological stress. Summary statistics for the mixed ANOVA of the LF/HF Ratio (Tilt Data – Pre-Tilt Data) over the four Trials and compared to the ESS, POMS, and SLSS is presented in Table 2.
Table 2

*Difference in LF/HF Ratio (Tilt Data – Pre-Tilt Data) over the 4 Trials and compared to the ESS, POMS, and SLSS (questionnaires were used as covariates)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>F Value</th>
<th>d.f.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial</td>
<td>2.34</td>
<td>18</td>
<td>0.1071</td>
</tr>
<tr>
<td>Trial (LF/HF Ratio) x ESS</td>
<td>1.65</td>
<td>18</td>
<td>0.2061</td>
</tr>
<tr>
<td>Trial</td>
<td>1.23</td>
<td>18</td>
<td>0.3268</td>
</tr>
<tr>
<td>Trial (LF/HF Ratio) x POMS</td>
<td>0.41</td>
<td>18</td>
<td>0.7984</td>
</tr>
<tr>
<td>Trial</td>
<td>1.16</td>
<td>18</td>
<td>0.3527</td>
</tr>
<tr>
<td>Trial (LF/HF Ratio) x SLSS</td>
<td>1.18</td>
<td>18</td>
<td>0.3520</td>
</tr>
</tbody>
</table>

*Epworth Sleepiness Scale (ESS) over the 4 Trials where the Trial 1-4 Effects were used as covariates (Pre-Tilt, Tilt, and Post-Tilt)*

The amount of training over time (4-months of competitive training and competition) does not seem to affect the participant’s ESS questionnaire results even when considering the LF, HF, and LF/HF Ratio (under all conditions: Pre-Tilt/Tilt/Post-Tilt) as a covariate factor in the ANCOVA analysis (based on all p values < 0.05). P > 0.05, where F = 2.15; d.f. = 38; P = 0.0937, is not significant. There is no difference between Pre-Tilt LF/HF Ratio and the ESS questionnaire in Trial 1.

*Profile of Mood States (POMS) over the 4 Trials where the Trial 1-4 Effects were used as covariates (Pre-Tilt, Tilt, and Post-Tilt)*

The amount of training over time (4-months of competitive training and competition) does not seem to affect the participant’s POMS questionnaire results even
when considering the LF, HF, and LF/HF Ratio (under all conditions: Pre-Tilt/Tilt/Post-Tilt) as a covariate factor in the ANCOVA analysis (based on all p values < 0.05), except for the case with Pre-Tilt LF (ms²) power as a covariate factor (F = 3.86; d.f. = 38; P = 0.0099) when in Trial 4. POMS values were higher with higher LF. Results are presented in Table 3.

Table 3

Profile of Mood States (POMS) over the 4 Trials where the Trial 1-4 Effects were used as covariates (Pre-Tilt, Tilt, and Post-Tilt)

<table>
<thead>
<tr>
<th>Variable</th>
<th>F Value</th>
<th>d.f.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial x Pre-Tilt LF (ms²)</td>
<td>3.86</td>
<td>38</td>
<td>0.0099</td>
</tr>
</tbody>
</table>

Self-Loathing Subscale (SLSS) over the 4 Trials where the Trial 1-4 Effects were used as covariates (Pre-Tilt, Tilt, and Post-Tilt)

No significant interactions were found with the SLSS questionnaire results response, under all conditions (Pre-Tilt/Tilt/Post-Tilt) as a covariate factor.
Chapter IV

Discussion

The purpose of this research study was to examine in-seasonal changes in selected physiological (HRV) and psychological (POMS Standard Form questionnaire, SLSS questionnaire where four SLSS questions were derived from the EOQ, and ESS questionnaire) measures, and relate them to training over time (4-months of competitive training and competitions) in women collegiate track and field athletes during a competitive collegiate season.

The LF/HF Ratio has been shown to be a reliable indicator in evaluating the ANS, sympathetic/parasympathetic balance, by using heart rate variability to monitor its adaptation to physiological stress. Low Frequency, which consists of sympathetic and parasympathetic activity, shows that after a physiological stress has been applied to the heart and the increase in HR does not seem to decrease or recover quickly after the applied stress, means that there is less variability with the R-R interval of heart beats. High Frequency, which consists of parasympathetic activity that influences the sinoatrial node of the heart, shows that with a decrease in HR soon after a physiological stress has been applied to the heart, there is more variability with the R-R interval of heart beats. The value of LF/HF Ratio, which has been a "widely used heart rate variability index of sympathovagal balance between the two branches of the ANS" (Burr, 2007), indicates how much each sympathetic/parasympathetic activity is being stressed by monitoring it via heart rate variability. Burr (2007) indicates that the LF and HF power band measures are almost always present together, or in conjunction with the LF/HF Ratio. Burr (2007) continues with,
"...each of the normalized spectral values is exactly predictable from the other by means of a simple linear relationship... These 2 normalized spectral heart rate variability indices are mutually redundant and equivalent carriers of the same information content... few seem to realize that the normalized spectral heart rate variability indices LF\textsuperscript{nu} and HF\textsuperscript{nu} are each linked to the LF/HF Ratio with simple reversible 1-to-1 algebraic mappings". (p. 914)

In regards to Burr's findings that LF and HF are basically linked to the LF/HF Ratio, it was decided to concentrate on the LF/HF Ratio when analyzing the heart rate variability data. This allowed the research to concentrate on the balance between the sympathetic and parasympathetic activity of the ANS. If there is an increase in sympathetic modulation, a decrease in parasympathetic modulation will be present, therefore, the heart is not responding well to the physiological stress of the tilt table. This implies that the heart is not in good condition and that the athlete has not received enough rest between workouts, therefore, suggesting that the athlete has been overtrained.

**Difference in LF/HF Ratio (Tilt Data – Pre-Tilt Data) over the 4 Trials**

When analyzing the data and looking at the difference between the LF/HF Ratio, Tilt Data minus Pre-Tilt Data, over the four Trials, we found that the amount of training over the four Trials does not seem to affect the participant’s ability to respond to physiological stress when tilted to an upright head-up tilt of 70°. \( P > 0.05 \), where \( P = 0.3876 \), therefore showing no significant differences over Trials 1-4. This could be due to the small sample size of participants (n=15) who volunteered for this research study and the participant’s specific event track and field background as well.
The participants of this study were made up of women distance runners, middle distance runners, heptathletes, sprinters, hurdlers, jumpers, and throwers. It would be interesting to separate the athletes according to their specific track and field event and analyze their data to see how they differ over the four Trials. It may be a possibility that there is a significant difference in LF/HF Ratio over time with the distance runners, but not with the throwers, due to the different physiological stresses that are demanded of their bodies because of their different events. The distance runners could run, for example, 60+ miles per week, whereas the throwers would not need to run that far and only run about 10 miles per week. These two extremes in data would cancel each other out during the analysis process, therefore, showing up in the results as not having a significant effect over time.

Difference in LF/HF Ratio (Tilt Data - Pre-Tilt Data) over the 4 Trials and compared to the ESS, POMS, and SLSS (questionnaires were used as covariates) (Table 2)

The amount of training over time (4-months of competitive training and competition) does not seem to affect the participant's Trials 1-4 results (LF/HF Ratio) when using the ESS questionnaire, POMS Standard Form questionnaire, and SLSS questionnaire (where four questions were derived from the EOQ questionnaire that was given to the participants) results as a covariate factor in the ANCOVA analysis (based on all p values < 0.05). The ESS questionnaire, which was used as a covariate to the Trials over 4-months, concludes that P = 0.1071 is not significant; however, appears to be approaching significance. Results suggest that there is no difference between all four Trials and the ESS questionnaire. This suggests that the physiological stress that was applied to the heart, over time (4-months) started to stress the heart and it slowly started
to affect the participant’s sleep, becoming more sleep deprived. However, a bigger sample of participants needs to be tested to confirm these findings.

The POMS questionnaire ($p > 0.05$, where $P = 0.3268$) and the SLSS questionnaire ($p > 0.05$, where $P = 0.3527$) showed that the amount of training over the four Trials did not seem to affect the participant’s ability to respond to physiological stress, therefore, not affecting their self-perception, tendencies to be compulsive exercisers, or their mood. As described previously in “Difference in LF/HF Ratio (Tilt Data – Pre-Tilt Data) over the 4 Trials”, it may be possible that the different event specific training (i.e., distance runners verses throwers) could have cancelled each other out.

The following results were not originally part of the research hypothesis, however, the investigator was curious to know how the four Trials (over the 4-months of competitive training and competition) interacted with each questionnaire (ESS, POMS, SLSS where four questions were derived from the EOQ which was given to each participant), using the four Trials as covariates. Also, the investigator did not exclude LF and HF powers and only analyze the LF/HF Ratio as with the previous results. The investigator looked at the LF, HF, and LF/HF Ratio powers and found the following: *Epworth Sleepiness Scale (ESS) over the 4 Trials where the Trial 1-4 Effects were used as covariates (Pre-Tilt, Tilt, and Post-Tilt)*

The amount of training over time (4-months of competitive training and competition) does not seem to affect the participant’s ESS questionnaire results even when considering the LF, HF, and LF/HF Ratio (under all conditions: Pre-Tilt/Tilt/Post-Tilt) as a covariate factor in the ANCOVA analysis (based on all $p$ values $< 0.05$). $P >$
0.05, where \( P = 0.0937 \), is not significant; however, appears to be approaching significance. There is no difference between Pre-Tilt LF/HF Ratio and the ESS questionnaire in Trial 1, which responds to the beginning part of the participant’s track and field in-season training. This could be due to the participants having to train for longer periods of time per day (i.e., distance runners having a high volume of mileage prior to Trial 1), perhaps overexerting themselves, therefore, putting more demands on their bodies. Training for longer periods of time per day, 5-7 days per week, and adjusting to the workouts would make an athlete very tired, therefore, scoring higher on the ESS questionnaire in Trial 1.

*Profile of Mood States (POMS) over the 4 Trials where the Trial 1-4 Effects were used as covariates (Pre-Tilt, Tilt, and Post-Tilt) (Table 3)*

The amount of training over time (4-months of competitive training and competition) does not seem to affect the participant’s POMS questionnaire results even when considering the LF, HF, and LF/HF Ratio (under all conditions: Pre-Tilt/Tilt/Post-Tilt) as a covariate factor in the ANCOVA analysis (based on all \( p \) values < 0.05), except for the case with Pre-Tilt LF (ms\(^2\)) power as a covariate factor when in Trial 4. \( P < 0.05 \), where \( P = 0.0099 \) is significant, which showed POMS values were higher with higher LF, which corresponds to the very last part of the training period: WAC Championships.

The higher TMD scores from the POMS Standard Form questionnaire suggests that the participants are a lot moodier when tested at Trial 4 than they were when tested at Trial 1. It seems that with the increased physiological and psychological stresses put on the participants throughout the track and field season (i.e., competitive training and competitions) the participants LF modulation became higher (having an increase in HR)
therefore, having less variability when looking at their R-R intervals (less heart rate variability). These data suggest that the participants could be overtrained.

*Self-Loathing Subscale (SLSS) over the 4 Trials where the Trial 1-4Effects were used as covariates (Pre-Tilt, Tilt, and Post-Tilt)*

No significant interactions were found with the SLSS (four questions that were derived from the EOQ) questionnaire results response, under all conditions (Pre-Tilt/Tilt/Post-Tilt) as a covariate factor. This could be due to the small sample size of participants (n=15) who volunteered for this research study and the participant’s event specific track and field background as well.

As stated previously in “*Difference in LF/HF Ratio (Tilt Data – Pre-Tilt Data) over the 4 Trials*”, the participants are not all from the same track and field event. They do not all train the same and compete in the same events. It would be interesting to separate the athletes according to their specific track and field event and analyze their data to see how they differ over the four Trials. It may be a possibility that there is a significant difference in SLSS results over the four Trials, when using Trials 1-4 as a covariate, with the distance runners, but not with the throwers, due to the different physiological stresses’ that is demanded of their bodies because of their different track and field events. The distance runners may not want to add more weight or increase their muscle mass, therefore, closely monitoring everything that they did and ate. Throwers, on the other hand, may want to increase their muscle mass, incorporate more strength training exercises into their practices and eat more to gain more weight. These two extremes in data would cancel each other out during the analysis process, therefore, showing up in the results as not having a significant effect over time.
Results from this research study were limited due to the methodology associated with a developmental research design, such as this longitudinal and quasi-experimental research design with repeated measures. Additionally, several confounding effects such as being exposed to the three questionnaires on four separate occasions could have increased the participants’ knowledge and influenced their attitude and behavior, not disclosing to the investigator that they may have been under the influence of medications or performance enhancement supplements at the time of data collection, and feeling anxious that their confidentiality could be compromised, therefore, not disclosing valuable information to the investigator may have influenced the findings as well.

Efforts to counter the history threat included: issuing all of the participants the same instructions for participation in the research study, providing them all with the same questionnaires (POMS Standard Form, SLSS derived from the EOQ & ESS), and weekly training logs. Participants were issued identification numbers to keep their personal data confidential. The participants were asked to maintain their normal daily habits throughout the duration of the research study and there was no attempt to manipulate the participants’ training program for the purposes of this study. The weekly training logs served as a method for the participants to track their daily training exercises; however, the majority of the participants did not turn in completed weekly training logs, due to lapses in self-reporting. The participants were given the “Weekly Training Logs” to take home and fill out on a daily basis. The participants were reminded to return the “Weekly Training Logs” to the principal investigator or the team’s athletic trainer, who kept them in a secure location until the principal investigator picked them up, on a weekly basis. The participants were reminded at each testing session, weekly e-mail’s from the
principal investigator, and reminders from the team's athletic trainer. A reason for not turning in the "Weekly Training Logs" could be due to forgetfulness, not wanting to take the time to fill out the training logs, or feeling anxious that their confidentiality could be compromised.

Attempts to counter the experimental mortality threat involved a reward incentive. For each testing day in which the participants participated, they received a muffin, fruit, and drink after completing each test. Efforts to counter the threat of selection biases included the eliciting of volunteer participants and using these same participants at each testing. However, as the elicitation of volunteer participants was restricted to collegiate women track and field athletes between the ages of 18 and 24 years old, the applicability of this research study's results was limited and cannot be applied to the general population.

The participants' diets were not monitored throughout the research study, therefore, the participants could have been undernourished and/or dehydrated which would eventually cause them to possibly become ill and succumb to injuries (e.g., stress fractures). Although the participants were highly trained athletes, and had previously participated in track and field, at the very least in high school, the participants' levels of physical fitness were not determined, which could have had an effect on the results. The participants could have entered the research study in an overtrained state due to their previous months and/or years of training (e.g., running cross country and/or running in high school), which would also include the intensity level of their previous training. Practice effects may have had an influence on the outcome of the results, and were
difficult to counter within this style of research design due to repeating the testing protocol four times within a 4-month time span.

The participants’ answers on the three questionnaires could have had an effect on the results. Knowing that their personal information was going to be kept confidential, the participants should have felt comfortable to express how they were feeling based on the questionnaire criteria; however, the results could have been skewed due to the possibility that the participants’ false answers reflected the desired outcomes of the investigator.

The tilt table is used as an indicator to evaluate how the body is able to cope with physical stress. Looking at the conditions (Pre-Tilt/Tilt/Post-Tilt), those measurements did not seem to affect the participants. The hard physical in-season training that these participants’ had, 4-months of daily competitive training and weekly non-conference competition and WAC Championship meets, did not seem to affect the women’s ability to respond to physical stress (e.g., tilt table test protocol).

Lastly, the data collected in this research study may help to tailor future training protocols by establishing a relationship between minimally invasive methods (HRV, self-perception, compulsive exercising, mood, and sleep) with the training status and performance of athletes. These findings may be possible to detect the onset of overtraining by using these invasive methods.
Chapter V

Conclusions and Recommendations

The purpose of this research study was to examine in seasonal changes in selected physiological (HRV) and psychological (POMS Standard Form questionnaire, SLSS, where four SLSS questions were derived from the EOQ, and ESS questionnaire) measures, and relate them to training over time (4-months) in female collegiate track and field athletes during a competitive collegiate season. No attempt was made to influence the participant’s training programs during the course of this research study. The data collected may help to tailor training protocols by establishing a relationship between minimally invasive methods (HRV, self-perception, compulsive exercising, mood, and sleep) with the training status and performance of women’s collegiate track and field athletes.

The following null research statements were addressed and the following null hypotheses conclusions were drawn:

Null Research Statements

The following null research statements were addressed:

1. There will be no difference between the amount of high in-seasonal training that the collegiate track and field women received over a period of 4-months (competitive training and competitions) and their ability to respond to stress.

2. There will be no difference between the amount of high in-seasonal training that the collegiate track and field women received over a period of 4-months (competitive training and competitions) and their self-perception, tendency to develop compulsive exercising behavior, mood disturbance, and sleepiness level.
Null Hypotheses Conclusions

1. Results from the ANOVA analyses (based on all p values < 0.05) indicate that there were no significant differences in LF/HF Ratio (Tilt Data – Pre-Tilt Data) over the four Trials due to the amount of high in-seasonal training that the collegiate track and field women received over a period of 4-months (competitive training and competitions). The physiological stress from the tilt table testing did not seem to affect the participants’ ability to adapt to physiological stress over the four Trials, thereby confirming the null hypothesis.

2. Results from the ANCOVA analyses (based on all p values < 0.05) indicate that there were no significant differences with the amount of training over time (4-months of competitive training and competition) and the participant’s Trials 1-4 results (LF/HF Ratio) when using the POMS Standard Form questionnaire results as a covariate factor in the ANCOVA analysis, thereby confirming the null hypothesis.

Results from the ANCOVA analyses (based on all p values < 0.05) indicate that there were no significant differences with the amount of training over time (4-months of competitive training and competition) and the participant’s Trials 1-4 results (LF/HF Ratio) when using the SLSS questionnaire results as a covariate factor in the ANCOVA analysis, thereby confirming the null hypothesis.

Results from the ANCOVA analyses (based on all p values < 0.05) indicate that there were no significant differences (P = 0.1071) with the amount of training over time (4-months of competitive training and competition) and the participant’s Trials 1-4 results (LF/HF Ratio) when using the ESS questionnaire results as a covariate factor in the ANCOVA analysis, thereby accepting the null hypothesis.
Recommendations

1. An in-season research study incorporating the use of female/male athletes, from different collegiate team sports, as participants should be conducted to gather more information to see how their heart adapts to different types and intensities of training throughout their competitive season.

2. A 4-year longitudinal research study incorporating the use of female/male athletes, from different sports, as participants should be conducted to gather more information to see how their heart adapts to different types and intensities of training throughout their season, beginning with their Freshmen year and ending with their Senior year in college.

3. A research study incorporating the use of female athletes as participants should be conducted where they would wear a Mini Logger to record heart rate during their sleep, twice during the study: once during a light training period and once during a heavy training period, to determine if there is a relationship with sleep and the athletes’ heart rate variability.

4. A research study incorporating the use of female athletes as participants should be conducted during a competitive season where they controlled their breathing (12 breaths·min⁻¹) in the supine position at rest during the ECG tilt table testing to determine if there is a relationship with controlled breathing and the athlete’s heart rate variability. Controlled breathing during a 70° head-up tilt table testing protocol was performed by Hedelin, Kenttä, Wiklund, Bjerle, and Henriksson-Larsen, 2000 and Hedelin, Wiklund, et al., 2000.
5. A research study incorporating the use of female athletes as participants should be conducted during a competitive season where they would wear a Mini Logger to record heart rate data during their sleep, twice during the study: once during a light training period and once during a heavy training period, to determine if there is a relationship with sleep and the athletes' heart rate variability.

6. Tighter participant criterion to ensure the amount of training background each participant must possess prior to inclusion in the research study.

7. A research study incorporating the same protocol from this study, but keeping track of the female athletes menstrual phases at baseline and throughout the study.

8. A research study incorporating the same protocol from this study, but use Time Domain Frequency (FFT) when analyzing the results.

9. A research study incorporating the same protocol from this study, using track and field athletes; however, separating the runners from the field event athletes.
Chapter VI

Review of Literature

Heart Rate Variability and Training Volume

Iellamo, et al. (2004) tested the hypothesis that training-induced variations in T-wave amplitude at higher training loads are paralleled by changes in heart rate spectral profile. The protocol consisted of evaluating eight male (age: 22.6 ± 2.8) senior rowers of the Italian national team, in their last scheduled training macrocycle of their conditioning period that culminated with the 2002 Rowing World Championship, at 50% and 100% of their training load, approximately 20-days before the 2002 World Championship, and during the 2002 World Championship, when the intensity was markedly reduced. Evaluation at 50% training load was performed approximately 3-months before the 2002 World Championship. Training routines consisted of 2 daily sessions, 7-days a week (26–30-hours per week). The differences between 50% and 100% training load consisted mainly in the amount of kilometers rowed associated with variations in the number of repetitions for each distance rowed and in the distance itself. The amount of repetitions and intensity of the strength exercises varied at the different training loads, as well as the amount of field running. During the World Championships, training consisted mainly of rowing on a boat, with no varying distances. They also assessed T-wave amplitude in chest lead V6 and cardiac autonomic regulation by power spectral analysis of R-R interval variability.

Results indicated that the increase in training load from 50% to 100% was accompanied by a significant decrease in HF and a significant increase in LF R-R variability (in normalized units) with a concomitant significant decrease in T-wave
amplitude. Reduction in the training load during the 2002 World Championship resulted in a return of spectral profile to the level observed at 50% training load and in a partial recovery of T-wave amplitude. Iellamo, et al. (2004) observed a shift from vagal to sympathetic predominance when the training load increased from submaximal to the maximum at the time of nearing the World Championship competition, as indicated by the marked increases in the LF component and in the LF/HF Ratio and by the drastic decrease in HF component of heart rate variability (in normalized units), respectively. Heart rate did not change significantly.

**Heart Rate Variability Following Intensified Training**

Evidence from cross-sectional studies has shown that trained athletes have a higher heart rate variability than untrained individuals (Achten & Jeukendrup, 2003). Unfortunately, there have only been a few longitudinal studies addressing heart rate variability in athletes following periods of intensified training. Achten and Jeukendrup (2003) stated that “only a few studies have investigated heart rate variability changes after a period of intensified training and no firm conclusions can be drawn from these results.” Since heart rate variability is believed to be reduced in a state of overtraining, researchers have focused attention on heart rate variability when training load is dramatically increased.

Pichot, Busso, Roche, Garet, Costes, Duverney, Lacour, and Barthélémy (2002) were investigating for practical and reliable markers of fatigue with the use of heart rate variability analysis. They wanted to assess the potential use of heart rate variability analysis as a biomarker in the control of the impact of successive increasing training loads on fitness and performance. The training protocol consisted of the evaluation of six
sedentary men (age: 32.7 ± 5.0) who went through successive 2-months of intensive physical training and 1-month of overload training on the cycloergometer followed by 2-weeks of recovery. Maximal power output over 5-minutes (Plim5'), VO2peak and standard indices of heart rate variability were monitored throughout the protocol.

Results indicated that during the intensive training period, physical performance increased significantly (VO2peak: +20.2%, p < 0.01; Plim5': +26.4%, p < 0.0001) as well as most of the indices of heart rate variability (mean RR, Ptot, HF, rMSSD, pNN50, SDNNIDX, SDNN, all p < 0.05) with a significant shift in the ANS toward a predominance of its parasympathetic arm (LF/HF Ratio, LFnu, HFnu, p < 0.01). They also found that during the overload training period, there was a stagnation of the parasympathetic indices associated with a progressive increase in sympathetic activity (LF/HF Ratio, p < 0.05). During the week of recovery, there was a sudden significant rebound of the parasympathetic activity (mean RR, HF, pNN50, rMSSD, all p < 0.05). After 7-weeks of recovery, all heart rate variability indices tended to return to the pre-study values. Pichot, et al. (2002) stated that “heart rate variability analysis appears to be an appropriate tool to monitor the effects of physical training loads on performance and fitness, and could eventually be used to prevent overtraining states.”

Hedelin, Kenttä, Wiklund, Bjerle, and Henriksson-Larsén (2000) were investigating the changes in performance, heart rate variability, and blood-chemical parameters over a 6-day training camp. The training protocol consisted of cross-country skiing and strength training. This training protocol increased the training load by 50% (13.0 ± 1.6 h), compared with their weekly training during the preceding month, in nine (six men and three women) elite international-class canoeists (age: 18-23), who were all
members of either the Swedish National A or B team. The participants had a competitive background of 6-14 years. Twenty-five percent was high-intensity/anaerobic training, 65% was endurance training (consisted almost exclusively of cross-country skiing), and 10% was strength training. Intensities were based on ratings of perceived exertion (RPE). Participants were only allowed to train easy or not at all on the afternoon before the final test day. An incremental treadmill test was performed before and after the increase in training load. The increase in training load caused a significant reduction in time to exhaustion, VO\textsubscript{2} max, and maximum lactate. Heart rate variability was also measured before and after the intensified training both in the supine position and after a tilt to 70\textdegree upright position. There were no significant changes between any of the measurements for HF power, LF power, or total power in the supine position or following the tilt test.

Hedelin, Kenttä, et al. (2000) also stated that a 6-day training period probably had a small effect on each participant’s heart rate variability and that group differences in heart rate variability will be difficult to detect in small groups. Their results suggested that heart rate variability was not a sensitive method to monitor overtraining in this protocol.

Portier, Louisy, Laude, Berthelot, and Guezennec (2001) measured heart rate variability in nine (six men and three women, age: 29-35) national class half-marathon and marathon runners, who had participated in running and competition intensively for 15 years, after a relative rest period of 3-weeks and after an intense training period of 12-weeks. One participant was withdrawn from the experiment because of too many premature ventricular contractions. Another was eliminated at the end of the study because of the absence of variability of HR, due to taking antidepressants. Results showed that LF power was significantly lower in the lying position following intense
training. High frequency power increased significantly with the tilt test. LF/HF ratio decreased significantly in response to the tilt test. These results support the use of heart rate variability as a means of evaluating the autonomic response to periods of high training.

**Heart Rate Variability and Overtraining**

Hedelin, Wiklund, et al. (2000) investigated whether spectral analysis of heart rate variability can confirm the increased parasympathetic activity suggested in the overtraining syndrome. They examined a male junior cross-country skier (age: 16) who had a decline in competitive performance. While performing standardized bicycle work, early breathlessness during training sessions and accumulated central fatigue occurred. The participant was strongly urged to rest and after a recovery period of almost 2-months he regained his previous work capacity. Data were collected after several months of intensive training, peaking at 20-hours of training per week.

Tests results of the junior cross-country skier indicated that the HF power and total power in the lying position were increased. The HF power returned to lower values after a recovery period of nearly 2-months. Tests for infections, pulmonary function, and exercise ECG were all normal/negative. Hemoglobin, white blood cells, ferritin, and cortisol were in the normal range. Profile of Mood States changed from an “iceberg” shape with a global score (G) of 110 to a G-score of 132, which was due to the increases in tension (7→17, healthy vs. overtrained), anger (8→14), and in depression-scores (3→14) despite a relatively unchanged vigor score. Since this was a case study, Hedelin, Wiklund, et al. (2000), stated that these findings are difficult to interpret and “need to be confirmed in more subjects.” However, the findings do suggest that changes in heart rate
variability might be a useful marker in the determination of overtraining when used in combination with various psychological profiles.

Uusitalo, et al. (1999) investigated heavy training- and overtraining-induced changes in HR and blood pressure variability (BPV) during supine rest and in response to head-up tilt in female endurance athletes. Fifteen healthy female endurance athletes, who had trained for at least 1-year prior to the experiment and had no history of smoking, participated in this study. The women athletes were divided into two homogenous groups by the researchers: an experimental training group (ETG) of nine athletes (age: 23.9 ± 3.0) and six control group athletes (CG) (age: 23.1 ± 2.7) gave their consent to participate in this study over a period of 6-9 weeks. The training protocol for the ETG athletes consisted of intensive training, 7-days a week, which included interval running (5-12 kilometers with a 2-minute rest in between) and continuous fast running (5-12 kilometers). The low-intensity training consisted mostly of long-term running (50-minutes to 3-hours) and also cycling, cross-country skiing, and swimming. The volume of intensive training was increased by one exercise session each week, starting with one session and a treadmill test during the first week. Low-intensity training volume was planned to increase by 7-10% each week. The CG athletes were allowed to train according to their own training program. Two days prior to collecting data, both the ETG and CG groups had a low-intensity training session which lasted for less than an hour. All training sessions were controlled by heart rate monitors (Polar Electro Sport Tester™, Kempele, Finland) and subjective feelings were recorded every day.

The purpose of this experimental training period was to overtrain the ETG athletes to meet the experimental research criteria of what an overtrained athlete should
look like. The criteria of overtraining were as follows: decreased maximal oxygen uptake by at least 2 ml x kg\(^{-1}\) x min\(^{-1}\), decreased maximal treadmill performance; unwillingness to train and the feeling of inability to go on training in combination with some of the overtraining signs and symptoms. These overtraining signs and symptoms include mood disturbances (decreased positive feelings: energetic, helpful, calm, vigorous, relaxed, confident and increased negative feelings: irritable, depressed, moody, fatigued, anxious, confused, excited, desperate, unable to concentrate), sleeping problems, menstrual irregularities, poor appetite, shaky hands, sweating or other psychosomatic symptoms, and no illness, injury or other explaining factor for the performance decrement. Five ETG athletes were diagnosed as being overtrained and they formed a subgroup of overtrained athletes (OA subgroup) (Uusitalo, et al., 1999).

The athletes went through an identical series of measurements which were repeated at baseline, after 4-weeks of training, when the athletes met the overtrained criteria or were physically and/or mentally exhausted after 6-9 weeks of training (END), and after 4-6 weeks of recovery training (RE). The measurements consisted of HR and BP and heart rate and BPV during a 5-minute supine rest and in response to a head-up tilt test, HR and blood lactate concentration during a submaximal treadmill running test, and a maximal oxygen uptake (VO\(_{2}\)max) test on a treadmill (Uusitalo, et al., 1999).

The results indicated a decrease from 53.0 ± 2.2 milliliters (ml) x kilogram (kg)\(^{-1}\) x min\(^{-1}\) to 50.2 ± 2.3 ml x kg\(^{-1}\) x min\(^{-1}\) (mean ± SEM, p < 0.01) in the 5 experimental athletes who were diagnosed as being overtrained (OA subgroup). The VO\(_{2}\)max of the ETG and CG athletes did not change. The decrease in VO\(_{2}\)max was accompanied by a significant increase in LF power, in the ETG athletes, during supine rest from 6 ± 1
millisecond (ms)$^2 \times 10^2$ to $9 \pm 2$ ms$^2 \times 10^2 (p < 0.05)$. This increase in LF power was also observed in seven elite Italian junior national team of rowing, who had increased their training load, prior to the Junior Rowing World Championships (Iellamo, et al., 2002).

Pichot, et al. (2000) designed a training cycle of 3-weeks of exhaustive training, allowing recovery for seven male middle-distance runners who had been practicing this sport for more than 3-years and were ranked at the national level in France. Each week, each athlete had his ECG recorded twice a week; recordings began 1-hour after an intensive training session and the other 1-hour after an extensive training session. Training load and fatigue scoring were evaluated weekly. The control subjects, eight healthy sedentary male students who did not practice any physical training activity, had their ECG’s recorded twice a week using the ambulatory Holter system (Stratascan 563, Del Mar). They were asked to avoid intensive physical activity during the 4-week recording period. Both groups were asked to avoid coffee and alcohol intake the day prior to the recordings.

In order to get a better understanding of how the athletes were responding to the training program, daily and weekly training loads were monitored as well as fatigue sensations of the athletes. Four different types of training sessions were defined for the athletes so that they could evaluate their weekly training load according to training intensity. Daily training load scores were based on the activity chart recorded each day by each athlete with the help of his coach. Weekly training loads were calculated as the sum of the daily scores. Athletes noted feelings of fatigue daily.

Each athlete’s R-R interval was analyzed using an ECG Holter system (Stratascan 563, Del Mar) with a precision of 0.008 seconds. These R-R intervals were analyzed only
during the night periods in order to avoid variations that could be introduced by differences in physical activity or by the environment. The beginning and the end of the sleeping periods were determined from the activity questionnaires and verified from the 24-hour R-R interval plots. Each recording of the mean HR (beats per minute [bpm]) and indices of heart rate variability was calculated on a continuous 4-hour period, between 0:00 and 4:00 a.m. Fast Fourier transfer indices were calculated on sets of 256 consecutive R-R intervals during the night periods, while the power spectrum indices were calculated as recommended by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (Pichot, et al., 2000).

Results demonstrated a significant and progressive decrease in parasympathetic indices of up to -41% during the 3-weeks of heavy training, followed by a significant increase during the relative resting week of up to +46%. The indices of sympathetic activity followed the opposite trend, first up to +31% and then -24%, respectively. The percentage increase in mean nocturnal heart rate variation remained below 12%. There was no significant variation in the control group. Pichot, et al. (2000) confirmed that heavy training shifted the cardiac autonomic balance toward a predominance of the sympathetic over the parasympathetic drive. Heart rate variability appeared to be a better tool than resting HR, when recorded during the night, to evaluate cumulated physical fatigue, as it magnified the induced changes in the ANS activity. These findings could be of interest to coaches and athletes to optimizing individual training profiles.
Waldeck and Lambert (2003) investigated the HR of 10 female participants (age: 18-45), who were recruited at a local health club, for 24-hours on three occasions over 3-weeks while the participants’ training status remained unchanged. The aim of this study was to assess the repeatability of monitoring HR during sleep when training status remained unchanged, to determine if this measurement had sufficient precision to be used as a marker of training status. Monitoring took place on the same day of each week. Each session consisted of a 24-hour monitoring day that started upon waking before the participant got out of bed. Heart rate was recorded every minute over the 24-hour period (in total 1440-minutes) and stored in the HR monitor (Polar Vantage XL, Kempele, Finland) for analysis at a later stage. The starting time of sleep was determined through subjective self-reporting by the participants. Participants were encouraged to maintain their normal lifestyles while being monitored, and were also requested to replicate their activity and dietary intakes, including caffeine as closely as possible on each of the three monitoring sessions by using the activity and nutritional records which were given to them as reminders at the orientation session. The participants’ compliance to the protocol were assessed at each testing session by comparing records of the previous week to the current week and discussing this with the participants. The study was designed to represent a typical field study situation. Therefore, the conditions of the study were matched to the conditions in which the monitoring would usually take place with athletes.

Test results indicated that the average HR of the group during sleep was similar on each of the three tests (65 ± 9, 63 ± 6, and 67 ± 7 beats·min⁻¹ respectively). The range in minimum HR variation during sleep for all participants over the 3 testing sessions was
from 0 to 10 beats · min⁻¹ (mean = 5 ± 3 beats · min⁻¹) and for maximum HR variation was 2 to 31 beats · min⁻¹ (mean = 13 ± 9 beats · min⁻¹). It was found that on an individual basis the minimum HR during sleep varied by about 8 beats · min⁻¹. This was a very important finding because it suggested that changes in the minimum HR during sleep needed to be greater than about 10 beats · min⁻¹ in order for it to be detected with any degree of confidence. An important factor to consider before changes in HR data can be interpreted with any degree of accuracy is to collect data on the intrinsic day-to-day variation in HR during sleep. Waldeck and Lambert (2003) indicated that this study would have been better if the participants had been tested in a controlled laboratory environment and had their stage of the menstrual cycle controlled. In addition, Uusitalo, Uusitalo, and Rusko (1998) indicated that in women the effect of menstruation should be taken into consideration and not be completely excluded.

*Heart Rate Variability and the Menstrual Cycle*

Aubert, Seps, and Beckers (2003) wrote that the menstrual cycle has been shown to affect the cardiac autonomic function as assessed by heart rate variability methods. Regulation of the autonomic tone is modified during the menstrual cycle. Changes in the cardiac autonomic activity may possibly be due to alterations in the balance of the ovarian hormones. Results suggest that parasympathetic nerve activity is predominant in the follicular phase. However, only a few studies have been researched in regards to young female athletes. These studies did not mention timing of the menstrual cycle.

Janse de Jonge (2003) found that plasma volume expansion associated with an increased stroke volume and decreased HR due to changes in blood viscosity and central venous pressure will result in changes in plasma volume over the menstrual cycle, which
may alter HR throughout the menstrual cycle. It has been shown that with an increase in HR there is an increase in body temperature, at a rate of 7 beats per minute for each 1ºC rise in core temperature.

Heart Rate Variability and Profile of Mood States

Verde, Thomas, and Shephard (1992) investigated 10 highly trained distance runners who undertook a 38% increment increase of training over a 3-week period. Although the full clinical picture of overtraining did not develop, the participants' running performance did not improve, and six of the 10 participants developed sustained fatigue. The POMS was the best single marker of disturbed function, indicating increased fatigue and decreased vigor. There were no useful changes of resting HR or perceived exertion during submaximal running, sleep was undisturbed, and there were no orthopedic injuries. The increase of serum cortisol normally induced by 30-minutes of submaximal exercise was no longer seen when the same acute exercise was performed after heavy training. Verde, et al. (1992) indicated that minor and transient changes of immune function could be a warning that training is becoming excessive, however, they only have a limited significance for overall immune function.
Appendix A

Approval for Research

Protection of Human Studies

Assurance Identification/IRB Certification/Declaration of Exemption

University of Hawaiʻi at Mānoa Research Services
Protection of Human Subjects  
Assurance Identification/IRB Certification/Declaration of Exemption  
(Common Rule)

| Policy: Research activities involving human subjects may not be conducted or supported by the Department and Agencies adopting the Common Rule (45CFR46.002, June 18, 1981) unless the activities are exempt from or approved in accordance with the Common Rule. See section 101(b) of the Common Rule for exemptions. Institutions submitting applications or proposals for support must submit certification of appropriate Institutional Review Board (IRB) review and approval to the Department or Agency in accordance with the Common Rule. 

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8. Assurance Status of this Project (Respond to one of the following)

[ ] This Assurance, on file with Department of Health and Human Services, covers this activity.
Assurance Identification No. E-3526, the expiration date October 15, 2005, IRB Registration No. IORG0000199

[ ] This Assurance, on file with (agency/depd) Assurance No., the expiration date , IRB Registration/Identification No. , covers this activity.

[ ] No assurance has been filed for this institution. This institution declares that it will provide an Assurance and Certification of IRB review and approval upon request.

Exemption Status: Human subjects are involved, but this activity qualifies for exemption under Section 101(b), paragraph .

7. Certification of IRB Review (Respond to one of the following if you have an Assurance on file)

[ ] This activity has been reviewed and approved by the IRB in accordance with the Common Rule and any other governing regulations.

by: [ ] Full IRB Review on (date of IRB meeting ) or [ ] Expedited Review on December 14, 2004

[ ] If less than one year approval, provide expiration date .

[ ] This activity contains multiple projects, some of which have not been reviewed. The IRB has granted approval on condition that all projects covered by the Common Rule will be reviewed and approved before they are initiated and that appropriate further certification will be submitted.

8. Comments

CHS #13411

9. The official signing below certifies that the information provided above is correct and that, as required, future reviews will be performed until study closure and certification will be provided.

11. Phone No. (with area code) (808) 956-5007

12. Fax No. (with area code) (808) 539-3954

13. Email: dendle@hawaii.edu

14. Name of Official William H. Dendle

15. Title Compliance Officer

17. Date December 16, 2004

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Appendix B

Packet Letter
To: Participant of the Heart Rate Variability Research Study

From: Lorita Leonhardt (Principal Investigator)

In this packet you will find:
- Agreement To Participate (4 pages)
- Medical History Questionnaire (1 page)
- PAR-Q & YOU (1 page)
- Training Logs (19 pages)
- Envelopes for your Training Logs (19 envelopes)

**Please bring the Agreement To Participate (Page 4), Medical History Questionnaire, and PAR-Q & YOU Questionnaire to your first testing session. I will contact you with the time and dates of your testing sessions. Thank you for your time.
Appendix C

Written Informed Consent Form

Agreement to Participate
I. Introduction

This study is a master's degree thesis for a University of Hawai‘i at Manoa graduate student.

One of the great unknowns of training athletes is how to monitor fatigue so that training load can be adjusted to achieve the desired results. In order to get optimal adaptations from your training, your fatigue levels should be monitored. There are times when fatigue is expected and perhaps even required to get the desired gains, but there are also times when excessive fatigue may limit the effectiveness of your training. The results of this study may help to develop an easy tool for coaches and athletes to use when monitoring training status.

Resting heart rate has been used for many years to track fatigue as a result of training. However, with so many external factors easily able to affect resting heart rate, more effective and reliable methods are being tested. Although the research is not conclusive, it may be possible to monitor your training status through the use of heart rate variability (HRV) analysis.

Heart rate variability is measured as the time between heartbeats, or the R-R interval. The R-R interval comes from measuring the time periods in milliseconds between beats. During periods of excessive training, the body may respond poorly to recovery, resulting in changes in HRV.

Training status has also been evaluated using various psychological scales which address mood states, sleep patterns, and self-perception. The purpose of this study is to monitor changes in these areas during your competitive season. This study is important because the normal changes in these variables that occur over time, for female athletes in response to training, have not been previously studied.
II. Procedure

Data will be collected following the start of the season, twice mid-season, and two weeks prior to the Western Athletic Conference (WAC) Championship meet. All tests will be performed in the Human Performance Laboratory in the Stan Sheriff Center at the University of Hawai'i at Manoa. You will be scheduled for a one hour test session between the hours of 6:30 A.M. and noon. You will be tested at the same time of day during the course of the season as described above. You will be instructed not to eat, train, drink caffeine or alcohol, smoke, or to use other substances, on the morning of your scheduled test. You may drink water and take any prescribed medication as instructed by your physician. We will try to accommodate your schedule so that we can test you soon after waking.

During the initial visit, you will complete an Exercise Orientation Questionnaire (EOQ), Profile of Mood States (POMS) questionnaire, Epworth Sleepiness Scale (ESS) questionnaire, and your height (cm) and weight (kg) will be taken. You will also undergo a seven-site skinfold test, which will be tested by a female member of the research team.

Next, heart rate variability will be measured for twenty minutes in the lying position, during a 70 degree upright tilt table test for five minutes, and back down to the lying position for another five minutes. You will be monitored for symptoms of feeling faint or dizzy during the tilt test. Heart rate variability will be measured during this period. You will have electrodes positioned on your chest by a female member of the research team. Four electrodes will be attached to the front of your chest, and one will be attached to the side of your chest. Twice during the study, once during a light training period and once during a heavy training period, you will be asked to wear a Mini Logger to record heart rate during your sleep.

As a subject, you will complete the POMS, EOQ, ESS, and heart rate variability testing protocols pre-season, twice mid-season, and two weeks prior to WAC Championships. You will be asked to keep a daily training log which will be e-mailed to the research team on a weekly basis.

Confidentiality

Participation in this study will be entirely voluntary. All information collected from you will remain confidential, to the extent allowed by law, and individual data will not be released to your coaches at any time. Group data will be available to the coaching staff at the end of the study, but your confidentiality will be maintained. A copy of your individual data may be obtained by you at the end of the study. Your normal training routine will be designed by your coach(s) and your training will not be interrupted by any member of the research team.

Information from this study may be used as part of scientific publication in medical or professional journals, but you will in no way be personally identified.
You will be given a unique identification number, which will be used instead of your name on forms and data folders. All of the data collected on you will be secured in locked file cabinets located at the University of Hawai‘i at Manoa’s Department of Kinesiology and Leisure Science and will be available only to members of the research team.

III. Right to Withdrawal or Removal from the Study

If at any time you no longer choose to continue with the study, you may withdraw without prejudice. Circumstance under which your participation may be terminated: (a) health conditions or other conditions that might occur which may be dangerous or detrimental to you or your health; (b) if it is determined that continued participation in this study may be harmful to you.

IV. Benefits

You may not directly benefit from this study although you will gain the experience of being part of a scientific experiment. The data collected from this study will allow for the evaluation of how you respond to training at the start of the season, twice mid-season, and two weeks prior to the WAC Championship. The data collected may lead to the future development of an instrument sensitive enough to detect extreme cases of fatigue.

V. Risks

Participation in this study will not expose you to risk beyond the normal risk of participating in collegiate sports. All of the procedures that will be used during the study are non invasive and will not interrupt your normal training routine. Every effort will be made to protect your privacy.

VI. Contact Information

If you have any questions about this project please contact Lorita Leonhardt (Principal Investigator) at 927-2318 or lleonhar@hawaii.edu. You can also contact Dr. Ronald Hetzler (Supervising Professor) at 956-7606 or hetzler@hawaii.edu.

Copy to Participant
VI. Certification

I certify that I have read and I understand the foregoing, that I have been given satisfactory answers to my inquiries concerning project procedures and other matters and that I have been advised that I am free to withdraw my consent and to discontinue participation in the projects or activity at any time without prejudice.

I herewith give my consent to participate in this project with the understanding that such consent does not waive any of my legal rights, nor does it release the principal investigator or the University of Hawai’i at Manoa or any employee or agent thereof from liability for negligence. 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.

Signature of Participant: ___________________________ Date: ____________

Printed Name: __________________________________________

If you cannot obtain satisfactory answers to your questions or have comments or complaints about your treatment in this study, contact: Committee on Human Studies, University of Hawaii, 2540 Maile Way, Honolulu, Hawaii 96822.

Phone: 808-956-5007
Appendix D

Medical History Questionnaire
Medical History Questionnaire

ID #: ________________________

Date: ________________________

Section 1

1) When was the last time you had a physical examination? ____________________________

2) Are you allergic to any medications, food, or other substances? Yes No
   -If yes, please list: __________________________________________________________

3) Please list your last three hospitalizations:

   Type of operation: ___________________ ___________________ ___________________
   Date: ___________________ ___________________ ___________________

Section 2: During the past 12 months...

1) Are you currently taking a prescription drug(s), herbal supplements, vitamins,
   or other nutritional supplements? Yes No

2) Has your weight fluctuated more than a few pounds? Yes No

3) Did you initiate this weight change through diet or exercise? Yes No

4) Have you experienced any faintness, lightheadedness, or blackouts? Yes No

5) Do you occasionally have trouble sleeping? Yes No

6) Have you had severe headaches? Yes No

7) Have you felt unusually nervous or anxious for no apparent reason? Yes No

Section 3: At present...

1) Do you experience sudden tingling, numbness, or loss of feeling in your arms,
   hands, legs, feet, or face? Yes No

2) Have you ever noticed your hands and feet feel cooler than the rest of
   your body? Yes No

3) Do you get pains and/or cramps in your legs? Yes No

4) Do you have diabetes? Yes No
   -If yes, how is it controlled? Diet Insulin Oral Medication Uncontrolled

5) How often would you characterize your stress level as high?
   Occasionally Frequently Constantly

Section 4: Family History

Has any of your immediate family had the following? What is the relationship to you?

1) Diabetes ____________________________

2) Heart Disease ____________________________

3) Stroke ____________________________

4) High Blood Pressure ____________________________

Thank You
Appendix E

Physical Activity Readiness Questionnaire (PAR-Q)
Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

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<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
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<tr>
<td>1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?</td>
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<tr>
<td>☐</td>
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<td>2. Do you feel pain in your chest when you do physical activity?</td>
<td>☐</td>
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<tr>
<td>☐</td>
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<tr>
<td>☐</td>
<td>☐</td>
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<tr>
<td>4. Do you lose your balance because of dizziness or do you ever lose consciousness?</td>
<td>☐</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?</td>
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<tr>
<td>☐</td>
<td>☐</td>
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<tr>
<td>6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?</td>
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<tr>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Do you know of any other reason why you should not do physical activity?</td>
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If you answered NO to all questions, you can be reasonably sure that you can:
• start becoming much more physically active - begin slowly and build up gradually. This is the safest and easiest way to go.
• take part in a fitness appraisal - this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

If you answered YES to one or more questions, talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.
• You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
• Find out which community programs are safe and helpful for you.

DELAY BECOMING MUCH MORE ACTIVE:
• if you are not feeling well because of a temporary illness such as a cold or a fever - wait until you feel better; or
• if you are or may be pregnant - talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ___________________________________________ DATE ______________________

SIGNATURE _________________________________________ WITNESS ______________________

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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Appendix F

Weekly Training Log
*Weekly Training Logs were provided for the months January to May

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<th>Training Phase: Competition</th>
<th>Pre Competition</th>
<th>Preparation</th>
<th>Transition</th>
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<td>Event: ______________________</td>
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**Weekly Goal:**

Ratings: Carry these out in the evening apart from Sleep Quality*

- 5= Great
- 4= Pretty Good
- 3= OK
- 2= Not So Good
- 1= Poor

** Muscle Soreness

- 5- Feel really good & light/ not heavy/
  not sore/ feel rested/ Great
- 4- Not heavy/ not sore/ a little tired/ Pretty Good
- 3- Not too sore/ not too tired / slight heaviness/ OK
- 2- Sore muscles/ feel heavy/ tired/ Not So Good
- 1- Muscles hurt a lot/ feel heavy/ strained/ injury/ Poor

**Rate level of Non-Athletic Stress for the week**

5- Very High; 4- High; 3-Medium; 2-Low; 1-Very Low

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<th>Waking Heart Rate</th>
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<td>Appetite</td>
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<td>Training Volume/Mileage:</td>
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<td>Is this a regular, light, or heavy period?</td>
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Thursday,
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Training Schedule: __________________________ Hours Sleep ________ Appetite 5 4 3 2 1
_____________________________ Motivation 5 4 3 2 1
_____________________________ Energy Levels 5 4 3 2 1
**Muscle Soreness 5 4 3 2 1
*Sleep Quality 5 4 3 2 1
Fatigue 5 4 3 2 1
Comments: ______________________________________________________

Friday,
Overall Performance Quality __________________ Waking Heart Rate ________ General Health 5 4 3 2 1
Training Schedule: __________________________ Hours Sleep ________ Appetite 5 4 3 2 1
_____________________________ Motivation 5 4 3 2 1
_____________________________ Energy Levels 5 4 3 2 1
**Muscle Soreness 5 4 3 2 1
*Sleep Quality 5 4 3 2 1
Fatigue 5 4 3 2 1
Comments: ______________________________________________________

Saturday,
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Training Schedule: __________________________ Hours Sleep ________ Appetite 5 4 3 2 1
_____________________________ Motivation 5 4 3 2 1
_____________________________ Energy Levels 5 4 3 2 1
**Muscle Soreness 5 4 3 2 1
*Sleep Quality 5 4 3 2 1
Fatigue 5 4 3 2 1
Comments: ______________________________________________________

Sunday,
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Training Schedule: __________________________ Hours Sleep ________ Appetite 5 4 3 2 1
_____________________________ Motivation 5 4 3 2 1
_____________________________ Energy Levels 5 4 3 2 1
**Muscle Soreness 5 4 3 2 1
*Sleep Quality 5 4 3 2 1
Fatigue 5 4 3 2 1
Comments: ______________________________________________________

If you have any questions about filling this form out, please contact Lorita Leonhardt at lleonhar@hawaii.edu.
Appendix G

Profile of Mood States (POMS) Standard Form Questionnaire
To the Administrator:
Place a checkmark in one box to specify the time period of interest.

To the Respondent:
Below is a list of words that describe feelings that people have. Please read each word carefully. Then circle the number that best describes:
- how you have been feeling during the PAST WEEK, INCLUDING TODAY.
- how you feel RIGHT NOW.
- other:

If no box is marked, please follow the instructions for the first box.

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<td>3</td>
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</table>

Please flip over.
Items continue on the back page...
### POMS™ Standard Form

**BY DOUGLAS M. McNAIR, Ph.D., MAURICE LORR, Ph.D., JW P. HEUCHERT, Ph.D., & LEO F. DROPLEMAN, Ph.D.**

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<th>Moderately</th>
<th>Quite a bit</th>
<th>Extremely</th>
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*Please ensure you have answered every item. Thank you for completing this questionnaire.*
Appendix H

Self-Loathing Subscale (SLSS) Questionnaire
Exercise Questionnaire (SLSS)

The following statements may or may not describe your feelings about exercise. Please circle the number that best describes how you agree or disagree with the statement. There are no right or wrong answers.

Strongly Disagree (1); Disagree (2); Uncertain (3); Agree (4); Strongly Agree (5)

1. I disliked my body before I began to exercise. 1...2...3...4...5
2. I am an active person. 1...2...3...4...5
3. I am dissatisfied with my performance. 1...2...3...4...5
4. I feel better after I exercise. 1...2...3...4...5
5. I hate my body when it won’t do what I want. 1...2...3...4...5
6. My best friends are athletic. 1...2...3...4...5
7. If I don’t reach my exercise goals, I feel like a failure. 1...2...3...4...5
8. I am a good athlete. 1...2...3...4...5

Thank you!

* The four bolded questions found on this SLSS questionnaire were identified on the Exercise Orientation Questionnaire, where those particular answers were then scored for the purposes of the research study as advised by Dr. Alayne Yates, M.D.
Appendix I

Exercise Orientation Questionnaire (EOQ)
EXERCISE ORIENTATION QUESTIONNAIRE

Name_________________________ Age____ Ht____ Wt____

The following statements may or may not describe your feelings about exercise. Read each statement and then circle the appropriate number to indicate how well the statement describes your feelings most of the time. There are no right or wrong answers.

Strongly Agree (5); Agree (4); Uncertain (3); Disagree (2); Strongly Disagree (1)

1. I try to exercise instead of snacking. 5........4........3........2........1
2. I very much want to control my weight. 5........4........3........2........1
3. Exercise keeps me from feeling bloated. 5........4........3........2........1
4. I disliked my body before I began to exercise. 5........4........3........2........1
5. I would like a lower percent body fat. 5........4........3........2........1
6. For me, exercising comes first. 5........4........3........2........1
7. I buy state of the art equipment to monitor/improve my performance. 5........4........3........2........1
8. I want to measure my performance (by time, distance, accuracy, etc.) 5........4........3........2........1
9. I am controlled by my training regimen. 5........4........3........2........1
10. I follow a regular exercise routine. 5........4........3........2........1
11. I strive for a personal best. 5........4........3........2........1
12. I need a goal to shoot for. 5........4........3........2........1
13. If I make one goal, I shoot for a harder one. 5........4........3........2........1
14. It is important for me to measure my performance accurately. 5........4........3........2........1
15. I am dissatisfied with my performance. 5........4........3........2........1
16. I choose to exercise rather than socialize. 5........4........3........2........1
17. I hate my body when it won't do what I want. 5........4........3........2........1
18. If I don't reach my exercise goals, I feel like a failure. 5........4........3........2........1
19. I am a serious athlete. 5........4........3........2........1
20. I am a good athlete. 5........4........3........2........1
21. My best friends are athletes. 5........4........3........2........1
22. I am an active person. 5........4........3........2........1
23. Exercise puts me more in control. 5........4........3........2........1
24. I exercise to get rid of frustration. 5........4........3........2........1
25. I feel better after I exercise. 5........4........3........2........1
26. Vigorous exercise gives me a "high". 5........4........3........2........1
27. I can organize my thoughts better when I exercise. 5........4........3........2........1

Thank you.
Appendix J

Epworth Sleepiness Scale (ESS) Questionnaire
The Epworth Sleepiness Scale

Name: ........................................................................................................................................

Date:..................................................................

Your age (Yrs)........ Your sex..........

How likely are you to doze off or fall asleep in the situations described in the box below, in contrast to feeling just tired?

This refers to your usual way of life in recent times.

Even if you haven’t done some of these things recently try to work out how they would affect you.

Use the following scale to choose the most appropriate number for each situation:

0 = would never doze

1 = Slight chance of dozing

2 = Moderate chance of dozing

3 = High chance of dozing

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<tr>
<th>Situation</th>
<th>Score</th>
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<td>Sitting and reading</td>
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<tr>
<td>Watching TV</td>
<td>[ ]</td>
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<tr>
<td>Sitting inactive in a public place (e.g. a theatre or meeting)</td>
<td>[ ]</td>
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<tr>
<td>As a passenger in a car for an hour without a break</td>
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<tr>
<td>Lying down to rest in the afternoon when circumstances permit</td>
<td>[ ]</td>
</tr>
<tr>
<td>Sitting and talking to someone</td>
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<tr>
<td>Sitting quietly after a lunch without alcohol</td>
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<td>Total</td>
<td>[ ]</td>
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</table>

The score is simply the addition of all eight answers. Less than 10 is considered normal.

Thank you for your co-operation

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Appendix K

Raw Data: Epworth Sleepiness Scale (ESS) Questionnaire Scores
### Epworth Sleepiness Scale scores over a 4-month period

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**Trial Totals**: 133 136 125 120

**Scale**:
- 0-5  Slight or no sleep debt
- 6-10  Moderate sleep debt
- 11-20  Heavy sleep debt
- 21-25  Extreme sleep debt
Appendix L

Raw Data: Profile of Mood States (POMS) Standard Form Questionnaire Scores
Profile of Mood States Standard Form Questionnaire Total Mood Disturbance (TMD) scores over a 4-month period

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Trial Totals 324 370 405 419
Appendix M

Raw Data: Self-Loathing Subscale (SLSS) Questionnaire Scores
Self-Loathing Subscale (where 4 questions were derived from the Exercise Orientation Questionnaire) scores over a 4-month period

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Trial Totals: 167, 177, 184, 178

Scale:
1-16 Normal/Healthy/Non-Clinical
16-20 High risk for an eating disorder and probably compulsive athleticism
Appendix N

Raw Data: Participant’s Demographics
Raw Data of the Participant's Demographics

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* Track and Field (T & F) Event Code:

1- Distance Runner: 3000m run, 5000m run, 10,000m run
2- Middle Distance Runner: 800m run, 1500m run
3- Heptathlete: 100m hurdles, high jump, shot put throw, 200m run, long jump, javelin throw, 800m run
4- Sprinter/Hurdler: 100m run, 200m run, 400m run, 110m high hurdles, 300m hurdles
5- Jumper: high jump, long jump, triple jump, pole vault
6- Thrower: shot put throw, discus throw, hammer throw, javelin throw
Appendix O

Raw Data: Absolute Difference in LF/HF Ratio (%) over Trials 1-4

(Tilt Data – Pre-Tilt Data)
Raw Data of the absolute difference in LF/HF Ratio (%) over Trials 1 and 2

(Tilt Data – Pre-Tilt Data)

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**Raw Data of the absolute difference in LF/HF Ratio (%) over Trials 3 and 4**

*(Tilt Data – Pre-Tilt Data)*

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References


Biomedical Signal Analysis Group. Heart Rate Variability Software (Version 1.1) [Computer software]. Department of Applied Physics, University of Kuopio, Finland.


Nasiff Associates Inc. CARDIO-CARD Software (Version 4.12) [Computer software]. Brewton, NY, USA.


