A CORRELATION BETWEEN HEART RATE VARIABILITY AND TAP TEST FOR DETERMINING EXERCISE PREPAREDNESS

A THESIS

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THESIS APPROVAL

Graduate Athletic Training Education

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INTRODUCTION

Heart rate variability (HRV) is defined as a natural phenomenon in which the timing between normal heart beats varies.[1] As a heart beat is recorded electronically via electrocardiogram (ECG), there is a large spike shown on the graph when the ventricles contract: this is known as the QRS wave complex. The R-R interval is the distance between two consecutive spikes (the R wave is the highest point on the ventricular spike, hence the R-R interval), and this distance is what is examined when HRV is calculated.[1,2] This measurement shows the regulation of heart rate by the autonomic nervous system.[1-3] The measurement and monitoring of that regulation has many different clinical applications, including determining health status, recovery, stress, fitness, and can also be used as a guideline for exercise prescription.[2-7] It is because of those many applications that this technique can be used in determining the exercise preparedness of an individual, which in turn will allow for more efficient training with improved results.

In determining preparedness, HRV measurements are typically compared to a baseline value, which can be obtained by doing a 7-day average. Once the baseline is obtained, the subjects will compare all new measurements to that baseline number, which will determine their readiness for exercise that day. If a measurement is found to be lower (more time between R intervals) than the average, the subject is physiologically less prepared for exercise. In contrast a subject whose measurement is higher (less time between R intervals) than baseline is physiologically well prepared for exercise. Multiple studies used this method,[4-7] and its benefits were shown in the significant results.

Athletes can benefit considerably from research on HRV, which can be seen in the results of a study done by Kiviniemi et al.,[4] where subjects performing a series of resistance training programs were found to have statistically significant increases in training load when HRV was used as a predictor compared to a control group and a predefined exercise group. Studies in which sport specific training groups were used (such as endurance athletes, including cycling, running, and ice hockey), also showed significant increases in performance for individuals who had a higher HRV measurements, and a subsequently poor performance when HRV was found to be low.[7,11-13] Using the

results from these studies, it shows us that HRV goes beyond heart function, but gives us an idea as to how an individual will perform based on their HRV measurement that day. Research in this area can continue to build on giving clinicians a guide for athletic performance and intensity guides.

The finger tap test (FTT) is a procedure that requires the subject to tap on a designated spot as many times as possible within a ten-second time frame. The tests have been used and proven valid both individually[8,9] and as part of a holistic testing method.[10] The FTT is typically used to test for autonomic brain function, such as in cases of brain trauma, brain diseases, and general neurocognitive testing.[8-10] Additionally, the FTT was recently strongly associated with CNS fatigue by as study that correlated subjects FTT scores and fatigue levels recorded prior to the testing.[11] The use of this testing method for autonomic function of the central nervous system is the reason for correlating with HRV, a measurement of autonomic heart function; the two measure autoregulation of important body functions.

This study examined any possible correlations between HRV testing and FTT testing, attempting to establish an acceptable level between the two measurements.

While the aforementioned studies have employed an ECG with an associated software program to determine HRV, a secondary aim of the proposed study attempted to find validity and reliability from novel technology: iThlete™. With this technology, one can use a halter strap heart rate monitor which communicates wirelessly with an inexpensive application (app) on a tablet or smart phone. This will allow the individual to monitor their HRV measurements and adjust their training protocols and intensities without the need for an expensive ECG machine.

To clarify, the primary purpose of this study was to correlate HRV measurements taken with an electrocardiogram to FTT scores. A secondary purpose of this study was to examine validity and reliability of the iThlete HRV software application.

METHODS

This section includes the following subsections: research design, subjects, instruments, procedures, hypotheses, and data analysis.

Research Design

This observational correlation research project explored the relationship between heart rate variability (HRV) as measured by Biopac® electrocardiogram (ECG) and the iThlete™ software system and the finger tap test (FTT). Additionally, the validity and reliability of the iThlete software system was examined in comparison with the Biopac® ECG. Subjects performed a finger tap test and had HRV measurements taken with both the iThlete HR monitor and Biopac ECG during 2 data collection sessions.[1-3]

Limitations of the study include:

- Inability to fully control the subjects' choices outside the testing conditions, such as sleeping

habits, alcohol use, drug use, stress levels, and practices and games.

- Inability to control for outside stress levels, and the subjects' neuromuscular learning patterns of the tap test conditions.
- Inability to extrapolate beyond the college-aged student and/or student athlete

Subjects

The subjects used in this study were 17 California University of Pennsylvania student-athletes undertaking strength and conditioning training with the University's strength and conditioning specialists. All subjects have completed a physical exam performed by California University of Pennsylvania team physicians and had been cleared for athletic activity. Furthermore, all subjects have no cardiac or orthopedic issues that would have precluded them from strength and conditioning training.

Inclusion criteria for this study included:

- Current varsity athlete at California University of Pennsylvania

- Current participant in strength and conditioning programs at California University of Pennsylvania

Exclusion criteria for this study included:

- Any documented cardiovascular condition
- Any person not yet medically cleared for sport participation

Preliminary Research

Initially, the Biopac, iThlete, and tap test procedures were tested on three volunteer athletic training graduate students prior to the start of the study. This was completed to ensure that testing procedures could be easily followed, established timing for the sessions, and familiarized the researcher with the equipment.

Instruments

Multiple instruments were used with this project including a Biopac ECG monitor and Acq*Knowledge* software run on a standard Windows run computer, iThlete and software run on an Apple iPad, and a finger tap test with questionnaire. Details for each instrument follows.

Biopac

An electrocardiogram (ECG) and amplifier from Biopac (BIOPAC Systems, Inc.; California, USA) had been used to assess heart rate variability. General purpose pre-gelled ECG electrodes (BIOPAC Systems, Inc.; California, USA) were connected via cable leads (BIOPAC Systems, Inc.; California, USA) from the subject to the ECG amplifier. The testing requires a 3-lead system, where the electrode placement would be medial to the anterior axillary fold of the left arm and right arms and just below the sternum. The ECG signal are sent to the computer, which is interfaced with Acq*Knowledge* (BIOPAC Systems, Inc.; California, USA) software for Windows to analyze the raw ECG R-R interval data for the HRV measurement in milliseconds.[1-3] This data was then recorded on the subjects data collection sheet for future comparison to the iThlete and FTT results.

iThlete

The iThlete (HRV Fit Ltd.; UK) software was downloaded to an iPad (Apple; California, USA). The iThlete communicates with a halter heart rate monitor (Cardiosport, UK) which was secured around the patient’s chest just below

the xyphoid process (the notch just below the breast bone, where the ribs converge). The heart rate monitor sends telemetric information to the receiver (HRV Fit Ltd., UK), which plugs into the headphone jack of the iPad. Once the heart rate signal had been received, HRV was interpreted by the open iThlete application on the iPad. The measurement was given as a numerical value, which was recorded on the subjects individual data collection sheet for future comparison between the Biopac and FTT results.

Finger Tap Test

The finger tap test (FTT) is a procedure that involves the subject tapping with the index finger on their dominant hand as many times as possible within a ten-second time frame, and scored as a single numerical value. In addition to the tap measurement, three questions (Appendix C3) were asked to obtain sleep quality (0-10, 0 being worst and 10 being best), mental stress level (0-10, 0 being worst and 10 being best), and how well they ate previous to testing (0-10, 0 being worst and 10 being best). This data was recorded on the subjects individual data collection sheet for future comparison between the Biopac and iThlete measurements.

Procedure

Subjects were recruited openly by the primary researcher after introduction by the strength and conditioning staff at California University of Pennsylvania during strength and conditioning sessions at the Hamer Hall strength and conditioning facility. All volunteers were participating in strength and conditioning exercise with the Cal U strength coaches. Volunteers were asked to participate after explanation of the project and question and answer time. An Informed Consent Form (Appendix C1) was obtained from each subject prior to participation in the study. The study was approved by the Institutional Review Board (Appendix C2) at California University of Pennsylvania. Each participant's identity remained confidential on the data collection sheets and did not included identifying information during the study.

As the subjects arrived at the athletic training facility inside Hamer Hall, they answered three questions pertaining to sleep quality, diet quality of the previous day, and level of mental stress, which was located on the individual's data collection sheet (Appendix C3). Subjects were then asked to sit in a dark, quite room for ten

minutes to rest with no physical stresses in order to record HRV in a resting state.

Following ten minutes of rest, the subject was then connected to the Biopac ECG and iThlete HR monitor strap. Simultaneous measurements for HRV were performed with each device and recorded for each subject and each device. Each subject performed the FTT, with the results recorded and logged, which concluded the session for that day.

To test reliability of the iThlete software, the procedure was repeated a second time under identical conditions one week apart. For example, if the original testing took place on a Monday morning, the subjects was asked back on the following Monday at the same time, to the same facility. The procedure was followed precisely, and all steps were repeated to maintain reliable testing conditions.

Demographic information for each subject was obtained during the first session and recorded on the individuals data collection sheet (Appendix C3). All test results (FTT, ECG HRV, iThlete HRV) were also recorded on that individual’s anonymous data collection sheet (Appendix C3). HRV and FTT results were recorded as a numerical value.

Hypotheses

The following hypotheses are based on previous research and the researcher's intuition:

1. There will be a strong, positive correlation between the finger tap test and HRV measurements (Biopac and iThlete).
2. HRV measurements from the iThlete device will be found to have acceptable reliability using Pearson Correlation.
3. The iThlete device will be found to correlate with measures from the Biopac device.

Data Analysis

All data were analyzed by SPSS (version 18.0) for Windows at an alpha level of 0.05. The research hypothesis was analyzed using a Pearson product correlation between FTT results and HRV measurements from both the Biopac and iThlete devices. Two additional Pearson product correlations were run: one for validity, comparing the scores to the already valid Biopac; and one for

reliability, comparing the scores of the iThlete testing sessions.

RESULTS

The purpose of this study was to determine if HRV measurements were correlated with the FTT to determine if an individual's FTT scores would predict preparedness for exercise. A second and third purpose of this research was to test the reliability and validity of the iThlete software, respectively. The following section contains the data collected and is divided into three subsections: Demographic Information, Hypotheses Testing, and Additional Findings.

Demographic Information

Eighteen healthy women and three healthy men who were current student-athletes enrolled in California University of Pennsylvania volunteered for this study. One female subject was excluded from the study due to technical difficulties during the first day of testing and a second female subject was excluded from Hypothesis #3 testing due to incomplete data. The remaining subjects (n = 17,

Hypothesis #1 and #3 testing; n = 16, Hypothesis #2 testing) were asked their height in centimeters, weight in kilograms, and age in years (Table 1).

Table 1. Subject demographic information.

Variable	Minimum	Maximum	Mean	Std. Deviation
Age (yrs)	18	21	19.78	.80
Height (cm)	158.5	190.5	171.5	2.63
Weight (kg)	56	100	74.7	10.82

Hypothesis Testing

It was hypothesized that the HRV measurements and the FTT scores would correlate, both for the Biopac device and the iThlete software.

A Pearson correlation coefficient was calculated for the relationship between the subjects' Biopac HRV measurement and the FTT results. No significant correlation was found. This research suggests that HRV measurements from the Biopac device are not related to an individual's FTT results.

A Pearson correlation coefficient was calculated for the relationship between the subjects' iThlete score and

the Biopac HRV measurement. A significant moderate positive correlation was found, this research suggests that the Biopac HRV measurements may predict iThlete HRV scores approximately 50% of the time. The results of the aforementioned correlation tests are found in Table 2.

Table 2. Pearson Product Correlation: Biopac, iThlete, and FTT.

		Biopac	**iThlete**	**FTT**
Biopac	Pearson Correlation	1	.339*	-.105
	Sig. (two-tailed)		.050	.554
	N	34	34	34
iThlete	Pearson Correlation	.339*	1	.209
	Sig. (two-tailed)	.050		.236
	N	34	34	34
FTT	Pearson Correlation	-.105	.209	1
	Sig. (two-tailed)	.554	.236	
	N	34	34	34

It was also hypothesized that iThlete would be found reliable between two different testing sessions by use of a Pearson correlation. When comparing the first and second testing sessions, no significant correlation was found. The results of the aforementioned hypothesis testing can be found in Table 3.

Table 3. Correlation: iThlete testing sessions 1 and 2.

		iThlete 1	iThlete 2
iThlete 1	Pearson Correlation	1	.365
	Sig. (2-tailed)		.164
	N	16	16
iThlete 2	Pearson Correlation	.365	1
	Sig. (2-tailed)	.164	
	N	16	16

Additional Findings

Additional Pearson correlation coefficients were calculated for three questionnaire questions (sleep level, diet quality, and stress level) against the Biopac, iThlete, and tap test results. No significant correlations were found. The results for the aforementioned correlations can be found in Table 4.

Table 4. Correlation: questions and measurements.

		Biopac	iThlete	FTT
Sleep	Pearson Correlation	.035	.297	.076
	Sig. (two-tailed)	.845	.089	.670
	N	34	34	34
Diet	Pearson Correlation	-.055	.235	-.099
	Sig. (two-tailed)	.235	.182	.577
	N	34	34	34
Stress	Pearson Correlation	-.247	-.053	.088
	Sig. (two-tailed)	.159	.764	.619
	N	34	34	34

This may suggest that the subjects’ sleep, diet, and stress levels cannot predict the HRV measurements and FTT results.

DISCUSSION

Discussion of Results

This study examined the relationship between heart rate variability (HRV) and the finger tap test (FTT). The scores of the FTT were compared to the HRV measurements of both the iThlete and Biopac devices to determine the ability to use the FTT in the clinic with confidence that it is a useful measurement tool for exercise preparedness. Additionally, reliability of a new HRV device and software, iThlete, was examined and compared to the already valid Biopac device.

When correlating the FTT with the Biopac and iThlete HRV measurements, no significant results were found. The FTT has been shown in the literature as being a valid tool for CNS function[12-14] yet is not related to either HRV measurements. This suggests the FTT score should not be used interchangeably to determine one's readiness for exercise.

This study compared HRV using two different devices: the Biopac ECG system and the iThlete software. When the

two were analyzed statistically using a correlation coefficient, there was a significant moderate positive correlation between the two measurements. This may suggest the validity of the iThlete device compared to a proven valid measure of HRV in the Biopac ECG device.[15-17] While additional research is warranted, this suggests that the iThlete may be used in place of the Biopac ECG and the scores can be used to determine exercise prescription. This type of result can also be seen in the recent validation of Polar heart rate monitors used to measure HRV. The initial validity was based on weak-moderate correlations, but through additional studies and compilation of data, strong correlations results came in favor of the Polar monitors.[18-20]

The measure of HRV is not a consistently similar score each time, but rather a dynamic score, fluctuating based on a person's level of fatigue, recovery, or nervous system efficiency.[21-23] It is this fluctuating relationship with the CNS that shows the inverse relationship between the parasympathetic (PNS) and sympathetic (SNS) nervous systems. As the SNS becomes more active in exercise, the PNS conversely becomes less active, and vice versa, HRV can be used to show this relationship and thus reflect upon the autonomic functions of the body.[23] With that information,

HRV looks specifically at the ratio between the two systems to determine if the individual is well prepared for exercise.[21-23]

This sparked other studies to look at HRV as an exercise predictor, both in exercise conditions and sport conditions.[4-5,9] The results of these studies showed that when HRV was found to be low prior to sport, that individual did not perform as well when compared to a day where HRV was high.[9] The researchers looked at ice hockey athletes, and measured their HRV daily and then coaches subjectively determined their athletic performance for that session. The results were then correlated, and significant findings showed when individuals had increased HRV prior to a session, they were evaluated higher by the coaches. This lead to the early conclusion that high HRV scores lead to increased performance.[9]

This early research is what drove the current study to look at other ways to determine exercise readiness, such as two different studies done by Kiviniemi et al.[4,5] The authors performed two separate studies looking at HRV as a predictor of exercise intensities. Following the conclusion of the exercise protocols, all training groups were shown to have significant increases in training loads

compared to control groups[4,5] and groups without HRV regulated exercise.[4]

With a finding of moderate validity, or relationship between Biopac and iThlete, a more economical, readily available device may be used in order to determine ones daily HRV score, as opposed to the gold standard electrocardiogram. Caution should be taken, however, as iThlete has only been shown to be accurate approximately 50% of the time. Given iThlete's simple, user-friendly interface and wireless monitor, there is no confusion due to a complex network of wires or extra steps for analysis on expensive equipment, such as with the Biopac. The Biopac required accurate placement of adhesive electrode pads which had wires attached, leading to the ECG device and then to the computer, and then additional software knowledge to select the correct test to be run, set the test parameters, and then get the measurement output. A person can purchase the iThlete sensor and receiver online, the iThlete app through your mobile device (which measures, calculates, analyzes, and stores your HRV measurement automatically), and spend less than $100.

When looking at the use of mobile analysis of HRV, the literature shows us that there are multiple options available as of late. Two different Polar devices (RS800

and S810/I models)[18-20] and Suunto device (t6 model)[20] have recently been validated and determined reliable and interchangeable methods of measuring HRV compared to a computer-based ECG device, however, the cost of these devices can be upwards of $350. With the demand for physiologic and HR guided exercise training continuing to grow among the athletic population, the iThlete device should be able to compete with these units with its self-contained analysis and cost effective hardware.

Conclusions

Collegiate student-athletes at the NCAA Division II level were used in this study. It should be noted that the results cannot be generalized to other populations, and further research is needed in order to obtain enough results for a greater generalization.

There were results suggesting a new method, in the form of iThlete, had moderate validity, but additional research is suggested to add to these findings. Having no significant correlation of the FTT to both Biopac and iThlete HRV also implies that there is no relationship between the FTT and HRV measurements on any device.

Recommendations

Future studies should focus their efforts on using a full, 12-lead ECG reading for HRV in order to obtain the most accurate measurements, but might also consider comparing the iThlete device to other recently validated mobile HR devices such as the Polar S810.

Future research should attempt to employ a greater number and diversity of subjects for generalization to a larger population.

The final suggestion for future researchers would be to use a computerized FTT battery, rather than relying on manual. There are protocols available that require specific positioning of other fingers to inhibit gross movement in order to rely on the target finger. In addition to a true FTT measure, it will provide a standardized scoring measurement that will be used across the entire sample grouping, improving accuracy, reliability, and feasibility for the researchers.

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APPENDICES

APPENDIX A

Review of Literature

REVIEW OF LITERATURE

This literature review will help determine the gaps in the current literature for the uses of heart rate variability (HRV) and the finger tap test (FTT). The review will look at different methods for measuring HRV, including different validated mobile-based devices, and its clinical applications. It will also look at the uses of the FTT and its clinical applications and possible crossover to sport and exercise.

Heart Rate Variability

Overview

Heart rate variability (HRV) is defined as a natural phenomenon in which the timing between normal heart beats varies.[1] As a heart beat is recorded electronically via electrocardiogram (ECG), there is a large spike shown on the graph when the ventricles contract: this is known as the QRS wave complex. The R-R interval is the distance between two consecutive spikes (the R wave is the highest point on the ventricular spike, hence the R-R interval),

and this distance is what is examined when HRV is calculated.[1,2] This measurement shows the regulation of heart rate by the autonomic nervous system.[1-3]

Segerstrom and Nes[4] looked to determine heart rate variability's relationship to one's ability to self-regulate, or to control emotions, thoughts, and impulses. They recruited 168 college-aged subjects to participate in study. Segerstrom and Nes examined food impulse and eating behavior. Subjects' feelings towards different types of food, whether or not they truly wanted to eat it, or if the impulse was caused by the fact the food was in front of them were among the variables examined. The results showed a higher change in HRV with those who ate carrots over cookies, as well as increased effort from those who ate carrots. They concluded that HRV and self-regulation were related, but more research is needed both in the lab and in the field.[4]

Mobile devices

As HRV-guided exercise increases in popularity, the amount of devices available will continue to increase. The devices range from wrist-worn watch devices of Polar™ and Suunto™ to the mobile device-based applications of iThlete™.

Weippert et al.[5] looked at two different mobile devices compared to an ECG unit for measuring HRV. The authors looked at the Polar S810i and Suunto t6 units, which use a chest strap heart rate monitor to collect the heart rhythm and are then sent to a wrist unit. The ECG used was an ambulatory, 5-lead design. Intra-class correlation coefficients were obtained for the three comparisons at a 95% confidence interval (Suunto vs. Polar [.999]; Polar vs. ECG [.996]; Suunto vs. ECG [.998]).[5] With the results, it can be said that the three units can be interchanged for HRV testing. The authors noted that it is not recommended to use different devices for intra-individual studies in order to maintain testing reliability.[5]

The Polar S810 was also looked at in a study done by Grossi Porto and Junqueira,[6] where they used the wrist worn Polar S810 and compared it to a conventional ECG set up. 33 individuals (15 men, 18 women; ages 18-42) were recruited for this study. The Polar S810 was compared to a 12-lead ECG. Using the Bland-Altman method and plot, the authors determined significant level of agreement between the two measurements. They further concluded that the use of the Polar S810 could be used for short-term measurement of HRV, but any measurement longer than 10-minutes would have to be examined further.[6]

In a study done by Wallen et al.,[7] the polar RS800 was examined in comparison to a traditional ECG unit. There was a total of 341 participants (139 men, mean age 52; 202 women, mean age 53).[7] The authors took simultaneous measurements of both the ECG and the Polar devices, of which were stored on a computer for analysis. Intra-class correlation coefficients at 95% confidence were found for each age group, each gender, and all data total. It was found that all age groups and genders had an average ICC of .930, with men averaging .968 and women averaging .898. All gender and age combinations were found significant with the exception of women over the age of 60 (there were no known reasons for this at the time of study). The data suggest the use of this new device on all populations with the exception of women over 60 years old.[7]

In a study done by Cassirame et al.[8] set out to examine the accuracy of the Minicardio system for assessing resting heart rate and HRV compared to a standard ECG recording. On 15 young participants, it was found that the heart rate was accurate with no artifacts between the two devices. Pearson coefficients were found to be 1.0 and .99 for both mean R-R interval and RMSSD, respectively.[8] They concluded that the use of Minicardio systems was to be encouraged and a portable recorder of heart rate and HRV.

Clinical applications

HRV has been examined in recent literature for its uses in sport exercise and performance, but additionally in its ability to predict fitness, sleep, and even guide neck-shoulder pain treatment.

Kiviniemi et al.[9] examined the use of HRV as a daily exercise prescription tool. In a study done in 2007, the authors recruited twenty-six males to participate in this study (8 in predefined training group, 9 in HRV determined group, and 9 in control group). The HRV group did either high intensity (high HRV) or low intensity/rest (low HRV/low HRV for consecutive days), while the predetermined group did a set intensity, and the control group participated in no exercise. Results showed the HRV group having a significant increase in both training load and oxygen consumption (VO2max), with no significant changed in VO2max, but a significant increase in training load. There were no changes reported in the control group.[9]

Kiviniemi[10] put together another study in 2010, where he and the co-authors used both men and women, and followed similar methods as their previous study from 2007. This study contained 4 groups, however; control, predetermined intensity, and then two HRV groups: HRV determined and HRV high intensity only. They came to the same conclusion as

their previous study, where there were significant training load increases in the HRV determined group compared to all other groups. They also determined that women gained a significant fitness improvement at a lower training load.[10]

Cipryan et al.[11] looked at the use of HRV in conjunction of coaches' performance evaluations to determine the usefulness of HRV in performance of hockey players in 2007. The subjects filled out a questionnaire prior to weekly HRV measurements inquiring about the previously training load, sleep duration and quality, and the athlete's perceived level of health. The coaches would then evaluate each player on a scale of 1-10 (10 being the best). The results showed that players with the highest HRV ratings were also the ones who had the most consistent ratings from their coaches. Also, the players with the lowest HRV scores showed to correspond with the lowest evaluations from the coaches, which is just as significant.[11]

Researchers grouped ice hockey players together, and monitored their HRV and skills in a study done in 2010 by Cipryan and Stejskal.[12] They set out to determine if grouping similarly monitored HRV individuals together would increase training effectiveness, reduce injury, and prevent overtraining. Upon the results, they showed that the

individuals with the same ANS activity benefited more from training, and suggest that team based on ANS monitoring and similar ANS reports would be beneficial.[12]

Sloan et al.[13] used exercise as an attempt to change the cardiac autonomic regulation variables in sedentary young adults. The authors had a total of 149 subjects using either aerobic or strength training in attempts to influence aerobic capacity, heart rate, and HRV. Following 12 weeks of protocol, they saw a significant change in the aerobic group only, including an increase in both aerobic capacity and HRV, and a decrease in heart rate. It was also interesting to note that the changes were only seen in men, and all levels returned to pre-testing levels following a 4-week deconditioning session.[13]

Military training was examined in this study by Jouanin et al.,[14] with emphasis put on HRV and recovery, fatigue, and performance, and blood tests were done to examine hormone levels. The subjects were put through a 15-week Ranger training camp, where they were expected to perform anaerobic, aerobic, and stressful tasks with compounded fatigue, meaning recovery was never possible. HRV increased significantly following the tests, suggesting that increased fatigue brings a subsequent increase in

parasympathetic activity rather than a decrease in sympathetic activity.[14]

Hallman et al.[15] sought out to use HRV as a biofeedback guide to treat stress related chronic neck/shoulder pain in twenty-four otherwise healthy subjects. The researchers grouped 12 participants in both a control group and an HRV biofeedback group for 10 weekly sessions. The biofeedback group showed an increased perception of health compared to the control group following the 10 sessions, suggesting HRV as an effective biofeedback marker.[15]

Finger Tap Test

The Finger tap Test (FTT) is a testing procedure in which a subject uses their dominant hand index finger to tap rapidly on a device for a set amount of time, typically 10 seconds. This procedure has many different uses and clinical applications, which will be examined further in the review of literature below.

Overview

In the book A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary, Strauss goes on to describe the uses and functions of the FTT.[16] In addition

to the FTT being effected by brain trauma, dementia, or motor dysfunctions of cerebellar or cerebral origins, the FTT results can be effected by chronic pain, attention, fatigue, or impaired ability to focus.[16] The author also goes on to explain further that not only should finger tapping speed be examined, but the tapping pattern as well. It is mentioned that individuals with traumatic brain injuries most commonly have an abnormal pattern rather than a decreased tapping speed, depending on the severity of the injury.[16]

Clinical Applications

In both a 1997 qualitative and quantitative study done by Prigatano and Hoffmann,[17] 30 patients were used with the use of the FTT to analyze brain dysfunction. Fifteen brain dysfunction patients and 15 normal controls were put through the protocol of the Halstead Finger Tapping Test. Upon conclusion, the authors determined that the brain dysfunction subjects had not only a slower tapping rate, but an abnormal pattern compared to the normal control subjects.[17]

Prigatano, Johnson, and Gale[18] went on to examine the effects of the Halstead Finger Tapping Test in individuals with traumatic brain injuries. In this study done in 2004,

the authors used subjects with an average of 18.5 years post-trauma, and noted that all subjects had normal or near-normal tapping times.[18] Subjects were asked to perform the FTT while undergoing a functional magnetic resonance image (fMRI). Following the imaging, it was seen that healthy controls showed a greater brain activation. The authors concluded that different level of brain activation can be seen in individuals suffering from traumatic brain injury even when performance is within normal limits.[18]

Gualtieri and Johnson[19] performed a validation study of a computerized testing battery called CNS Vital Signs (CNSVS), which is used to measure neurocognitive clinical screenings. The test is a combination of 7 other subtests: verbal and visual memory, finger tapping, symbol digit coding, the Stroop Test, a test of shifting attention, and the continuous performance test. The testing was found to be highly reliable between test-retest procedures, and additionally was found to be valid compared to the results of other testing batteries such as TOVA (Tests of Variables of Attention). Furthermore, they concluded that computerized testing methods showed a more consistent correlation coefficient, and have been shown to be more reliable with traumatic brain injuries, dementia, and ADHD.[19]

In an article by Emeljonavas, Poderys, and Venskaityte,[20] 70 boys between the ages of eleven and fourteen were examined for the effect of variable training on the dynamics of muscular, cardiovascular, and central nervous system (CNS). They used the FTT in order to determine the CNS involvement. They study concluded that boys ages 13-14 years had significantly increased CNS indices compares to the boys ages 11-12 years.[20]

In a study done by Haglund[21] out of the National Sports Center in St. Paul, MN, fourteen Division III collegiate athletes were asked to perform the FTT daily. In addition, they logged their perceived fatigue level and the difficulty of the previous day's workout. Upon completion of the analysis, the researcher found that CNS fatigue can be measured using the FTT and additionally, CNS fatigue may be affected by workout difficulty.[21]

Conclusion

In conclusion, the literature examined many different applications for both HRV measurements FTT results. In two studies done by Kiviniemi[9,10], both the importance and significance of HRV testing and exercise adaptation were outlined for clinicians dealing with athletes. In both

studies, HRV guided exercise intensity groups were shown to have statistically significant higher training loads compared to all other groups, including HR high intensity only group, control group, and non-HRV exercise group. Cipryan and Stejskal[12] also examined HRV with performance, but rather that using exercise, the authors paired the measurement with sport performance. The results went to suggest that athletes with higher HRV measurements had higher performance ratings and athletes that had low HRV measurements subsequently had lower performance ratings.. Using the HRV guided method, athletes can train more efficiently and gain better training outcomes, both in sport and exercise.

As the FTT was examined in literature, it was conclusive that the test was reliable and valid for measuring CNS efficiency and fatigue.[20,21] With heart rate and HRV being autonomic functions;[1-3] this is significant that it may also be related to exercise preparedness. The study done by Haglund[21] showed that FTT was strongly correlated with CNS fatigue and exercise intensity. This could be an important tool for clinicians to use at the conclusion of exercise to determine its difficulty.

APPENDIX B

The Problem

STATEMENT OF THE PROBLEM

Literature has extensively covered the topic of heart rate variability in terms of exercise response, prediction, and determination over a variety of subjects, including college-aged adults, sport teams, and even Army forces in order to uncover significance of heart rate variability in terms of training. One area that has been overlooked, however, is the use of heart rate variability to determine the readiness of an individual for training or exercise. The research being proposed will help to unveil additional findings that can help clarify the effectiveness.

Definition of Terms

The following definitions of terms will be defined for this study:

1) Heart rate variability – the body's natural phenomenon resulting in a fluctuation of timing between heart beats
2) Finger tap test – a testing battery that examines the efficiency of the autonomic nervous system by

measuring the number of taps in a 10-second time frame from the patient’s dominant index finer

Basic Assumptions

The following are basic assumptions of this study:

1) The information collected from the subjects will be able to be generalized to similar athletes.
2) The subjects will be honest when they complete their demographic sheets.
3) The equipment being used is appropriate and valid for measuring heart rate variability
4) The equipment was working properly and calibrated correctly.

Limitations of the Study

The following are possible limitations of the study:

1) The subjects may not show consistency in their preparedness questionnaire.
2) The training sessions being performed may not be sufficient to test the hypothesis.

Delimitations of the Study

The following are possible delimitations of the study:

1) The subjects were collegiate athletes from California University of Pennsylvania.
2) The subjects were that of a convenience sample.

Significance of the Study

This study will provide data to allow a clinician the ability to prescribe exercise based on the physiological status of the patient. This, in turn, will provide a better training experience for the patient, as well as provide a potential for increased performance and larger training gains.

Not only will patients be immediately benefited from this research, but new technology could become available that is more economical and widely available to the general public. This will allow patients to obtain their own readings and direct their own training without the need for a professional to guide them.

With the results of this study, athletes will be able to train more efficiently. Doors will also be opened for potential further application of heart rate variability and performance, program prescription, and exercise response.

APPENDIX C

Additional Methods

APPENDIX C1

Informed Consent Form

California University of Pennsylvania

Informed Consent Form

1. Brendon M. Jonsson, who is a Graduate Athletic Training Student at California University of Pennsylvania, has requested my participation in a research study at California University of Pennsylvania. The title of the research is *A CORRELATION BETWEEN HEART RATE VARIABILITY AND TAP TEST FOR DETERMINING EXERCISE PREPAREDNESS*.

2. I have been informed that the purpose of this study is to examine the use of heart rate variability as a daily determining factor for exercise preparedness to maximize an athlete's training efficiency. I understand that I must be 18 years of age or older to participate. I understand that I have been asked to participate along with 29 other individuals because I am clear of any orthopedic injuries as well as any cardiovascular conditions and because I am a student-athlete at CalU.

3. I have been invited to participate in this research project. My participation is voluntary and I can choose to discontinue my participation at any time without penalty or loss of benefits. My participation will involve:

I will undergo a single testing session on two separate occasions, one week apart, which will involve three different modalities. On test days, as the subjects arrive to the strength and conditioning facility inside Hamer Hall, they will fill out a brief questionnaire (attached) pertaining to sleep duration, level of mental stress, and how well they ate leading up to exercise. Subjects will then be asked to sit in a dark, quiet room for ten minutes to rest with no physical stresses in order to record HRV in a resting state.

Following ten minutes of rest, the subject will then be connected to the Biopac ECG and iThlete HR monitor strap. Simultaneous measurements for HRV will be performed with each device and recorded for each subject and each device. HRV is a passive measurement requiring no activity by the subject. Each subject will then perform the tap test, with the results recorded and logged, which will conclude the session.

4. I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. With participation in a research program such as this there is always the potential for unforeseeable risks as well. Subjects have the potential to incur minor sprains and strains to their dominant hand index finger during the tap test procedure. It is important to note that the Biopac and ithlete testing are passive measurements involving no activity from the subjects aside from sitting quietly while measurements are taken.

In the event that an injury does occur, they will receive initial treatment from the primary researcher, a licensed athletic trainer. Referral will be made to the Student Health Center should any additional care be needed. The cost of this care will be the responsibility of the participant.

For female participants: If I may become pregnant, the particular treatment or procedure may involve risks, foreseeable or currently unforeseeable, to the participant or to the embryo or fetus and I should discontinue participate.

5. I understand that, in case of injury, I can expect to receive treatment or care in Hamer Hall's Athletic Training Facility. This treatment will be provided by the researcher, Brendon M. Jonsson, under the supervision of the CalU athletic training faculty, all of which can administer emergency care. Additional services needed for prolonged care will be referred to the attending staff at the Downey Garofola Health Services located on campus.

6. There are no feasible alternative procedures available for this study.

7. I understand that the possible benefits of my participation in the research are to provide data which will allow a clinician the ability to adjust exercise intensity based on the physiological status of the patient according to their HRV. This, in turn, will provide a better training experience for the patient, as well as provide a potential for increased performance and larger training gains.

8. I understand that the results of the research study may be published but my name or identity will not be revealed. Only aggregate data will be reported. In order to maintain confidentially of my records, Brendon M. Jonsson will maintain all documents in a secure location on campus and password protect all electronic files so that only the student researcher and research advisor can access the data. Each subject will be given a specific subject number to represent his or her name so as to protect the anonymity of each subject.

9. I have been informed that I will not be compensated for my participation.

10. I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by:

Brendon M. Jonsson, LAT, ATC
STUDENT/PRIMARY RESEARCHER
JON8473@calu.edu
(716) 397-7640

Shelly DiCesaro, PhD, LAT, ATC
RESEARCH ADVISOR
dicesaro@calu.edu

(724) 938-4562

11. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.

12. I have read the above information and am electing to participate in this study. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

13. This study has been approved by the California University of Pennsylvania Institutional Review Board.

14. The IRB approval dates for this project are from: 03/29/13 to 03/28/14.

Subject's signature:_____ Date:_____

Witness signature:_____ Date:_____

APPENDIX C2

Institutional Review Board –

California University of Pennsylvania

Institutional Review Board
California University of Pennsylvania
Morgan Hall, Room 310
250 University Avenue
California, PA 15419
instreviewboard@calu.edu
Robert Skwarecki, Ph.D., CCC-SLP,Chair

Dear Mr. Jonsson:

Please consider this email as official notification that your proposal titled "A correlation between heart rate variability and tap test for determining exercise preparedness" (Proposal #12-062) has been approved by the California University of Pennsylvania Institutional Review Board as submitted.

The effective date of the approval is 3-29-2013 and the expiration date is 3-28-2014. These dates must appear on the consent form .
Please note that Federal Policy requires that you notify the IRB promptly regarding any of the following:

(1) Any additions or changes in procedures you might wish for your study (additions or changes must be approved by the IRB before they are implemented)
(2) Any events that affect the safety or well-being of subjects
(3) Any modifications of your study or other responses that are necessitated by any events reported in (2).
(4) To continue your research beyond the approval expiration date of 3-28-2014 you must file additional information to be considered for continuing review. Please contact instreviewboard@calu.edu

Please notify the Board when data collection is complete.
Regards,
Robert Skwarecki, Ph.D., CCC-SLP
Chair, Institutional Review Board

Appendix C3

Individual Data Collection Sheet

Individual Data Collection Sheet

Subject #: _____ Year school: _____

Gender: _____ Height: _____

Age: _____ Weight: _____

Subject:	***Session 1***	***Session 2***
Sleep quality?		
Diet quality?		
Stress level?		
Biopac HRV		
Ithlete HRV		
Tap test		

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ABSTRACT

TITLE: A Correlation Between Heart Rate Variability and Tap Test for Determining Exercise Preparedness

RESEARCHER: Brendon M. Jonsson

ADVISOR: Dr. Shelly DiCesaro

RESEARCH TYPE: Masters Thesis

PURPOSE: The purpose of this study is to correlate HRV measurements taken with an electrocardiogram to FTT scores. A secondary purpose of this study is to examine validity and reliability of the iThlete HRV software application through additional correlations.

METHOD: An observational correlation research project explored the relationship between heart rate variability and finger tap test. Subjects were 17 student-athletes from California University of Pennsylvania. All subjects participated in two testing sessions obtaining HRV (Biopac and iThlete) and FTT results, in addition to sleep, diet, and stress levels at time of measurement.

FINDINGS: Pearson correlation coefficients showed significant relationships for Biopac vs. iThlete (r = .339, p = .05), no significant results for both Biopac vs. FTT and iThlete vs. FTT. Pearson correlation coefficient for reliability of iThlete measurements session one versus session two were also had no significant findings. Additionally, there were no significant relationships found between any of the testing measurements and the questionnaire responses.

CONCLUSION: Results suggest iThlete has moderate level of validity, yet further research is needed to determine reliability of device. FTT should not be used as exercise predictor based on results of this study. Suggest further research with increased subjects and measurements, in addition to using computerized FTT battery over manual method.