

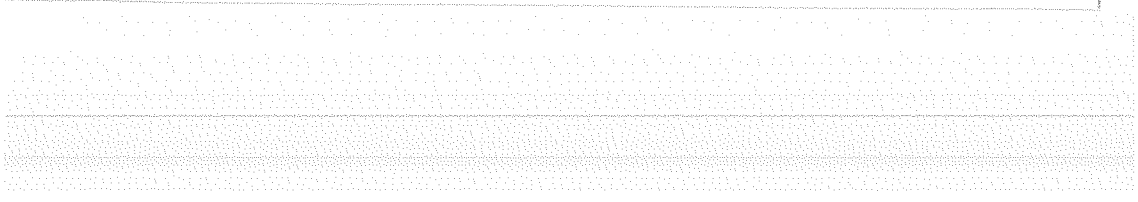
**Use Of Ratings Perceived Exertion And Heart Rate As An Indicator Of
Exercise Intwnsity During Agaded Intensity Tennis Cround Stroke**

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*Use of Ratings Perceived Exertion and Heart Rate
as an Indicator of Exercise Intensity During a
graded Intensity Tennis Ground Stroke*

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ABSTRACT

Six well-trained male Kuwait tennis players participated in the study. All of them had been involved in regular tennis training, \bar{x} age = 21.1 ± 1.36 yrs, \bar{x} height = 172.2 ± 14.8 cm, \bar{x} weight = 77.8 ± 11.0 kg, were subjected to test a graded ground strokes tennis skill levels. Measurements were obtained on heart rate and rating of perceived exertion responses during activity with the inclusion of tennis strokes return accuracy during the graded intensity ground strokes test. The relationship of heart rate to rating of perceived exertion were relatively high for activity ranging from 0.62 to 0.85 indicating that either method could be used for assessing stress of tennis play. The graded intensity ground strokes test proved to be very similar to in providing heart rate and RPE responses, and resulted in a correlation of 0.82 between stages of the test and % error of hitting to a target area, suggesting that it may have potential for assessing changes in level of tennis conditioning as well as stress of overtraining.

INTRODUCTION

The popularity of tennis has led to numerous studies of the sport and how it affects the athletes who participate in it. Concerns about the health of participants in all kinds of sports led to advances in game rules and coaching techniques. Ideas tested and validated in one sport were carried over into training for other sports. Technology, especially in the field of sports medicine, became an important part of the training program for athletes in all kinds of sports. Bergeron, Maresh, Kraemer, Abraham and Gabaree, 1991; Snyder, Jeukendrup and Hesselink, 1993 and Snyder, Kuipers and Keizer, 1998).

As he Vergauwen, Spaepen, Lefevre and Hespel, 1998 study demonstrates, there is very little actual information available on the use of RPE in tennis. There are also no recorded journal articles or researchers based on the RPE for tennis. Since RPE can be a useful tool in developing tennis skills and especially performance endurance, there is a strong need for studies that evaluate the validity of the Borg Scale as an indicator for tennis training.

The purpose of the current study is to investigate whether or not the Borg Scale and heart rate is a valid indicator of tennis exercise intensity for national Kuwait tennis team player. The result of this study could provide valuable measurements that can be used in determining activity intensity in tennis training. RPE and HR can help identify weaknesses and strengths in tennis players during training. It can also determine fatigue rates and overtraining problems. The ultimate purpose of the accumulation of this information is that coaches will be able to determine what training level is best for each player on the team. It would be possible to predict the probability of winning or losing a match based on the preceding events. In order words, weaknesses that lead to losses can be identified and avoided in both training and actual competition.

PURPOSES OF THE STUDY :

The primary purposes of this study to:

Investigate whether or not a modified version of the 10 point Borg scale is a valid indicator of training session intensity of rating of the perceived exertion works for Kuwait tennis players.

ASSUMPTIONS :

The results of this study will be interpreted with the following assumptions:

1. The data collected (RPE, and HR) during the field-testing is valid and reliable.
2. The subjects will be motivated to perform as requested in a test.

Research Questions :

1. Is there a relationship between RPE and heart rate max?
2. Is there a relationship between gold standard variables such as heart rate and RPE and the same variables in filed testing of a tennis player?
3. How does this effect heart rate response and RPE in the accuracy of measurement during ground stroke?

DEFINITION OF TERMS :

1. **Training Intensity:** The basic measurement of training intensity in this study is heart rate response (HR) to standardized exercise testing and/or tennis play.
2. **Rating of Perceived Exertion (RPE):** The rating of perceived exertion in this study is measured of the 10 point Borg scale which uses verbiage more familiar to athletes in assessing their intensity of exercise.
3. **Ground Stroke:** A shot that is hit with a forehand or backhand stroke after the ball has bounced on the court.
4. **Intensity:** The stress put in the heart; usually expressed in beats per minute.
5. **Interval Training:** Alternating work and rest bouts during exercise period.

REVIEW OF LITERATURE

Early studies of human performance and its relation to perceived exertion during physical activity have shown that, measuring heart rate (HR) and utilizing a rating of perceived exertion (RPE) scale to regulate exercise intensity, have been the most frequently used experimental methods. As noted by Dunbarm, Robertson, Baun, Blandin, Metz, Burdett and Goss (1967), this is because the RPE scale method requires little or no equipment and can be used in both clinical and sport applications.

Rating of perceived exertion (RPE), is a theoretical construct designed by Borg, who believed that measuring an athlete's feelings of exhaustion during exercise, by means of a categorical numerical scale, could provide useful insights into the physiological deterioration taking place within the human body during exercise (Borg, 1961).

The first study on RPE was carried out by Borg himself in 1962. In his study, Borg provided the basis for the number six to be the starting point of perceived exertion rather than zero. Borg supported his theory by providing the following logic: a low resting heart rate for the average adult is 60 (bpm); therefore, utilizing six as the starting point, rather than zero, allows simplistic use of numerical data as the rating can be multiplied by a factor of 10 to determine the approximate HR (i.e. 10 multiplied by 6 = 60 bpm), (Borg, 1962). Although the Borg scale was modified after this study to better correlate it with ratings and actual workload, the most important finding of Borg's research was a linear relationship of between RPE and HR (Carton and Rhodes, 1985).

Further research has concluded that this scale is applicable in a number of situations. The scale and its relatively high linear correlation of 0.85 between HR and RPE has been proven valid for both males and

females, individuals of varying fitness levels, use with bicycle or treadmill exercise, intermittent or continuous exercise, and use with arm or leg exercise (Skinner, Borg and Buskirk, 1969; Stamford, 1976; Michael and Eckhardt, 1972; Mihevic, 1983; Borg, 1973; Skinner, Hustler, Bergsteinova and Buskirk, 1973a; Edwards, Melcher, Hesser, Wigertz and Ekelund, 1972; Sargeant and Davies, 1973). Further, researchers have considered applying the scale in experiments that focus on cycling, jogging and treadmill and field running (Easton and Williams, 1986; Glass, Knowlton and Becque, 1992; Ceci and Hassmen, 1990).

The Borg Scale is the standard measurement used in testing the RPE of athletes in many different sports. It is commonly used for the subjective assessment of the degree of difficulty of physical tasks. The results from the Borg Scale are estimations of how the players actually sees his effort in the work. (Dumbar 1993).

Using Borg Scale in the Sports are an important tool to be used in sports studies. The Borg scale is inexpensive to administer and easy to use. Other advantages include, the RPE scale is generalized to a variety of populations and clinical subsets differing in gender, age, and athletic type, RPE has wide application in home-and hospital based rehabilitative programs, Category scales to assess RPE are reliable and valid psychophysical tools and Minimal scaling expertise is required on the part of the test administrator or the individual being tested, i.e., experimental subject, student athlete (Noble 1982; Pollock, Jackson, & Foster, 1986).

According to Easton, Davies, and Williams (1987) there are some practical applications of the use of the Borg Scale in determining RPE. They recommend that RPE be used to self regulate exercise intensity in any sport. Using male subjects in a laboratory setting, the researchers compared the results of three different exercise sessions. The results were positive for their study.

The purpose of a study by Stamford (1976) was to determine the reliability of the Borg (RPE) Scale under a variety of experimental conditions. The subjects of the study were 14 sedentary female college students. They performed six repeated work tasks distributed over four experimental testing sessions and presented in randomized order. The work tasks involved treadmill walking and jogging, cycling, and stool stepping. The validity of the Borg Scale was supported by this test. RPE responses were found to be highly reproducible Whether interval or terminal. High correlations were also terminal RPE responses. RPE demonstrated a strong relationship with HR and work intensity. It was concluded that category ratings of Perceived exertion according to the Borg (RPE) Scale offer a sensitive and reliable measure of Stress encountered during work. (Stamford 1976; Gilliam, Freedson, Geenen and Shahraray 1981)

Hogan and Fleishman(1979)reported a correlation of .83 between effort ratings and energy expenditure of 41 recreational activities. These studies lend support to the contention that the utilization of a category scale to measure perceived effort is both reliable and valid. The plasticity of reliability and validity from one condition or mode of exercise to another necessitates continuous experimental replication to be absolutely sure of the soundness of reported data and clinical diagnoses.

A study by Oconnor 1989; Oconnor, Morgan, and Reglin(1991), in sports with mixed efforts of varying duration the effort varies from low to moderate to extremely high or maximal. The RPE scale can be very helpful in avoiding overtraining in this type of sport. used the RPE scale during standardized training in swimming.

Kurokawa and Ueda (1992)tested the validity of RPE using four expereriment based on swimming training. The tests conducted in this study support the results of Borgs original study on aerobics. There was a strong linear relationship between RPE and HR at all levels of performance for the swimmers, both skilled and poorly skilled. The researchers concluded that adjusting exercise intensity through RPE is appropriate in skilled trained swimmers be HR coincided with RPE. However, in good skilled well trained swimmers, adjusting exercise intensity through RPE is underestimated at the low and middle exercise intensities (Kurokawa and Ueda 1992).

METHODOLOGY

Selection of Subjects :

Subjects Six well-trained male Kuwait tennis players participated in the study. All of them had been involved in regular tennis training for several hours per week for 9 male hours, aged 20-24 years, volunteered to participate in this study. All subjects signed written consent forms to participate in the field test protocols. The consent form, approved by the Department of PHYSICAL Education, indicated the expected benefits and possible discomforts involved with the testing protocol for a graded intensity tennis ground strokes test to exhaustion Prior to testing, subjects received a summarized explanation of the test protocol and the 10-point rating of perceived exertion RPE Borg scale Subjects were asked to familiarize themselves with the 10 point RPE chart prior to testing to ensure that the test scores would accurately reflected performance by the athletes. In addition to the consent forms, all subjects, completed a health questionnaire to assess their suitability to engage in maximal physical work.

Motivation of the Subjects :

Subject motivation and continued adherence to the test protocol were of vital importance during the study. All subjects were continuously supervised and verbally encouraged by the investigator and assistants in the field. Supervision provided valuable interaction with subject and enhanced feedback for proper test protocol procedures.

Method for measuring heart rate during the test protocol for this study :

Heart rate was measured every 5 seconds on a Polar Vantage XL monitor. The device consists of a microprocessor, which is worn on the wrist like a watch, and a small nylon strap that is placed around the chest. The monitor was easily assembled and recorded heart rate during the test protocol to measure activity intensity.

Explanation of Procedures and Equipment :

The test protocol consisted in one activities. All subjects participated in one activity for one day. activity employed exercise protocols was explained to the participants before engaging in the activity. subjects were asked to report their "perceived exertion" (how tired they were) by referring to the 10-point RPE Borg scale.

Activity: A graded intensity tennis ground strokes test to exhaustion.

In this field test, subjects were given a tennis stress test to the point of voluntary exhaustion. The test was conducted on an indoor tennis court. Before the test, subjects were given a short 10-minute warm-up (Shellock, 1986), to increase blood and muscle temperature, to facilitate performance (Elam, 1986), and to improve range of motion.

The test consisted of each player hitting the ball to a target area using both forehand and backhand ground strokes. Between hitting the ball, subjects returned to a center mark on the baseline. Each subject began by warming-up his ground strokes for 2 minutes, after which the frequency of feeding balls were increased (for example: warm-up, fed every 10 seconds; stage one, fed every 7 seconds; stage two, fed every 6 seconds; stage three, fed every 5 seconds; stage four, fed every 4 seconds; stage five, fed every 3 seconds; stage six, fed every 2 seconds; stage seven, fed every 1 second). The duration of the test was dependant on each subject's fitness level. Subjects continued the test until they reached voluntary exhaustion.

A polar heart rate monitor was used to record heart rate data. During the test, subjects were asked to report perceived exertion (RPE) using the method at the end of each 2-minute stage. Subjects were encouraged to reach a maximum heart rate during this test and then cool down prior to completion of the test by walking around the tennis court for 3 minutes. The entire testing sequence took approximately 30 minutes. The test was designed to simulate a maximal treadmill exercise test where subjects would normally walk or run to exhaustion in response to regular increases in speed and grade of the treadmill.

The following equipment was used in a graded intensity tennis ground strokes test to exhaustion:

1. Basket of new tennis balls (total of balls 175).
2. Subjects' tennis rackets.
3. Score sheets.
4. Tennis court.
5. Stopwatch.
6. Tape recorder to give feeding signal to investigator.
7. A 10-point RPE chart.
8. Two targeted areas on the tennis court (see figure in appendix A)

The following criteria were used to assist subjects in maintaining a focused effort throughout the test until voluntary exhaustion:

- 1- Heart rate and RPE were monitored every two minutes until maximal effort resulted in voluntary exhaustion.
- 2- After each ball was fed by the investigator, subjects hit the ball (after a bounce) at the baseline near the single's sideline.
- 3- Subjects hit each ball over the net and down the line to the appropriate targeted area (between the service line and the baseline and the single's sideline and the temporary line set 10 feet inside the single's sideline).
- 4- Accuracy was determined by the ability of each subject to place the forehand and backhand ground strokes into the designated target areas. Balls hit out of the targeted areas were labeled "balls-out" and balls hit in the targeted area were labeled "balls-in" (Appendix B).

Statistical analysis of the data : - 10 -

1. Descriptive statistics, including means, standard deviations, and ranges were determined for all dependent variables—including age, height (cm), weight (kg), resting heart rate (sitting) and (standing)—through computer program analysis (SPSS).
2. One-way repeated measure ANOVA was utilized to compare maximal HR in the graded exercise test against maximal HR in the tennis stress test and to reveal changes in HR and RPE between stages of the tennis ground strokes tennis test. In addition, regression analyses were performed to relate number of balls served against HR for tennis stress test.

RESULTS AND DISCUSSION

The primary purposes of this study were to build a tennis specific field test that would provide physiologic and perceived exertion and Heart rate responses similar to that of a graded intensity tennis ground strokes test to exhaustion protocol. This result presents of the statistical analysis under the following headings: a) characteristics of the subjects, and b) comparison of a ground stroke test with an RPE and HR.

Table 1

Descriptive statistics for physical and physiological characteristics of the subjects (N=6).

<i>Variable</i>	<i>Mean</i>	<i>± SD</i>
Age (yr)	21.07	± 01.36
Height (cm)	172.2	± 14.85
Weight (kg)	77.83	± 11.02
Max HR (bpm)	194.3	± 07.57
Resting HR (bpm)	59.05	± 04.93

Table 1 The means, and standard deviations of age, height, and weight for the subjects are presented in Table 1. These physical characteristics are very similar to Kuwait national tennis players subjects used in another tennis research study at the University of Connecticut by Bergeron, Marsh, Kraemer, Abraham & Gabaree, 1991. Their data indicated values for height of 176 ± 8.0 cm, and for weight at 72.8 ± 9.8 kilograms .

Table 2

An example of responses to activity (the graded intensity tennis ground strokes test in one subject).

Level	Time	HR	RPE	Balls IN	Balls Out	% error
Warm-up	0-2 min	98	1	10	2	16%
Stage-1	2-4 min	117	2	16	1	5.8%
Stage-2	4-6 min	137	3	19	1	5.0%
Stage-3	6-8 min	154	4	24	0	0%
Stage-4	8-10 min	162	5	27	3	10%
Stage-5	10-12 min	177	7	38	5	11.6%
Stage-6	12-14 min	188	8	47	13	21%
Stage-7	14-16 min	193	10	12	25	67.6%
Cool down	16-19 min	119	2	-	-	-

Shown above in Table 2 is an example of the data collection sheet for the graded intensity tennis ground strokes test to exhaustion in one subject which was stopped at 15:10 at a HR max of 193 bpm.

Note:

- Warm-up=12 balls(feeding the balls every 10 seconds).
- Stage-1=17 balls (feeding the balls every 7 seconds).
- Stage-2=20 balls (feeding the balls every 6 seconds).
- Stage-3=24 balls (feeding the balls every 5 seconds).
- Stage-4=30 balls (feeding the balls every 4 seconds).
- Stage-5=43 balls (feeding the balls every 3 seconds).
- Stage-6=60 balls (feeding the balls every 2 seconds).
- Stage-7=120 balls (feeding the balls every 1 second).
- Cool down-3 minutes walking around the tennis court.

The pattern of error rate as stages of the ground strokes tennis test increased was similar in virtually all subjects as that demonstrated by the subject in Table 2. A relatively low error rate was evident at the warm-up stage followed by a decreased in error rate through stage 3. Thereafter, mean error rate and variability of error increased as stages increased (see Table 3).

Table 3

Mean and standard deviations of ground stroke error rates at various stages of ground strokes tennis test of all subjects (N=6).

<i>Level</i>	<i>Mean</i>	<i>S.D.</i>
Warm-up	10.5%	5.66
Stage 1	5.85%	3.45
Stage 2	8.53%	3.65
Stage 3	5.77%	3.40
Stage 4	28.25%	9.95
Stage 5	41.77%	17.96
Stage 6	61.15%	21.65
Stage 7	80.86%	12.63

This demonstrates a relationship between error rate and fatigue which becomes most evident after stage 3.

Table 4

Descriptive Statistics for heart rate and RPE responses to the ground stroke tennis test. (N=6).

Level	RPE Mean \pm SD	HR (bpm) Mean \pm SD
Warm-up	01.66 \pm 0.52	093.33 \pm 13.45
Stage-1	02.50 \pm 0.55	105.00 \pm 19.66
Stage-2	03.00 \pm 0.00	119.83 \pm 21.08
Stage-3	03.66 \pm 0.52	133.66 \pm 23.96
Stage-4	04.66 \pm 1.03	153.33 \pm 19.98
Stage-5	06.66 \pm 1.03	174.50 \pm 13.12
Stage-6	09.00 \pm 1.09	187.83 \pm 09.80
Stage-7	10.00 \pm 0.00	194.50 \pm 07.42

Separate repeated measures ANOVAs were performed on HR and RPE data using Tukey's post hoc test at $p < .05$. Degrees of freedom (d.f.) were adjusted using Greenhouse Geisser epsilon (ϵ). For HR, $F = 91.84$, d.f. = 7, 7.54) and for RPE ($F = 127.52$, d.f. = 7, 8.52). See table 7 and 8 for results of Tukey's test.

Table 5

The Tukey post hoc (HSD) tests for the ground strokes tennis test for (HR) data from table 4 of all subjects (N=6).

Stage	Warm-up	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7
Warm-up	00.00	11.67	26.50	40.33*	60.00*	81.17*	94.50*	101.17*
Stage 1		00.00	14.83*	28.66*	48.33*	69.50*	82.83*	89.50*
Stage 2			00.00	13.83*	33.50*	54.67*	68.00*	74.67*
Stage 3				00.00	19.67*	40.87*	54.17*	60.84*
Stage 4					00.00	21.17*	34.50*	41.17*
Stage 5						00.00	13.33*	20.00*
Stage 6							00.00	06.67*
Stage 7								00.00

* $P < .05$

Note: The table above indicates the application of the Tukey HSD critical difference to the pairwise comparisons of the 7 stages for HR (bpm) of the ground stroke tennis test (N=6). Critical difference for Tukey's test = 38.08.

Table 6

The Tukey post hoc (HSD) tests for the ground strokes tennis test for (RPE) data from table 5 of all subjects (N=6).

Stage	Warm-up	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7
Warm-up	0.00	0.84	1.34	2.00	3.00*	5.00*	7.34*	8.34*
Stage 1		0.00	0.50	2.00	3.00*	5.00*	7.34*	7.50*
Stage 2			0.00	0.66	1.66	3.66*	6.00*	7.00*
Stage 3				0.00	1.00	3.00*	5.34*	6.34*
Stage 4					0.00	2.00	4.34*	5.34*
Stage 5						0.00	2.34*	3.34*
Stage 6							0.00	1.00
Stage 7								0.00

* P < .05

Note: The table above indicates the application of the Tukey HSD critical difference to the pairwise comparisons of the 7 stages for RPE of the ground stroke tennis test (N=6). Critical difference for Tukey's test = 2.44.

Table 4, 5 and 6 depict the means and standard deviations of heart rate responses and RPE for six players on the ground strokes tennis test. Note that heart rate responses (Table 5) are clearly more descriptive of the differences in stages than are the RPE scores. RPE does not discriminate between stages until stage 4. One might ask the question why one should not skip the first two or three stages and go directly to stage 4 to obtain meaningful data on stress. If this were done however potential discriminatory data would be lost relative to responses in the early stages which might have the potential to change dramatically with over-training. This remains to be confirmed using a larger number of tennis players who exhibit a wider variety of skill levels.

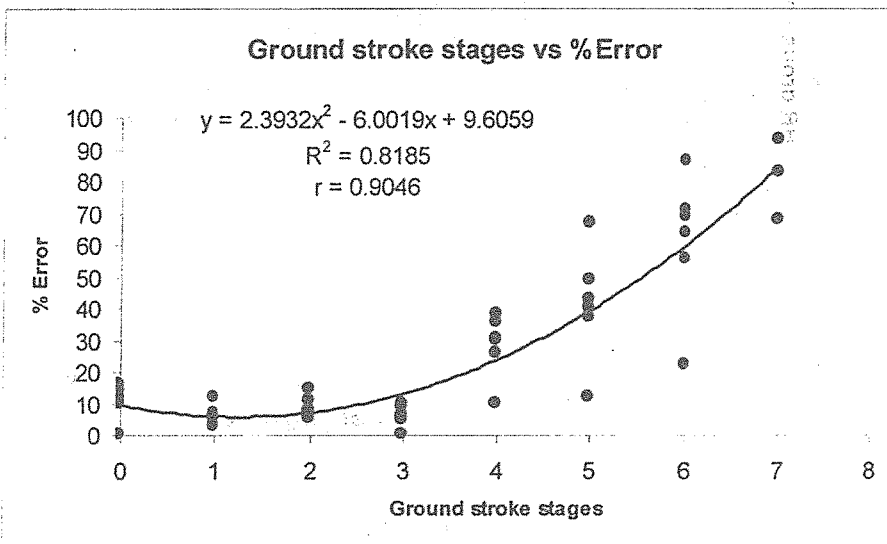


Figure 1

The relationship between % error of the balls hit during the ground stroke stages

Figure 1 displays the correlation between percent error rate in hitting tennis balls to a specific target and increasing intensity stages of tennis ball delivery. The relatively high correlation of 0.82 suggests that the grounds stroke test is clearly representative of a task that provides a reasonably incremental graded exercise test which affects player grounds stroke accuracy in a regular incremental way.

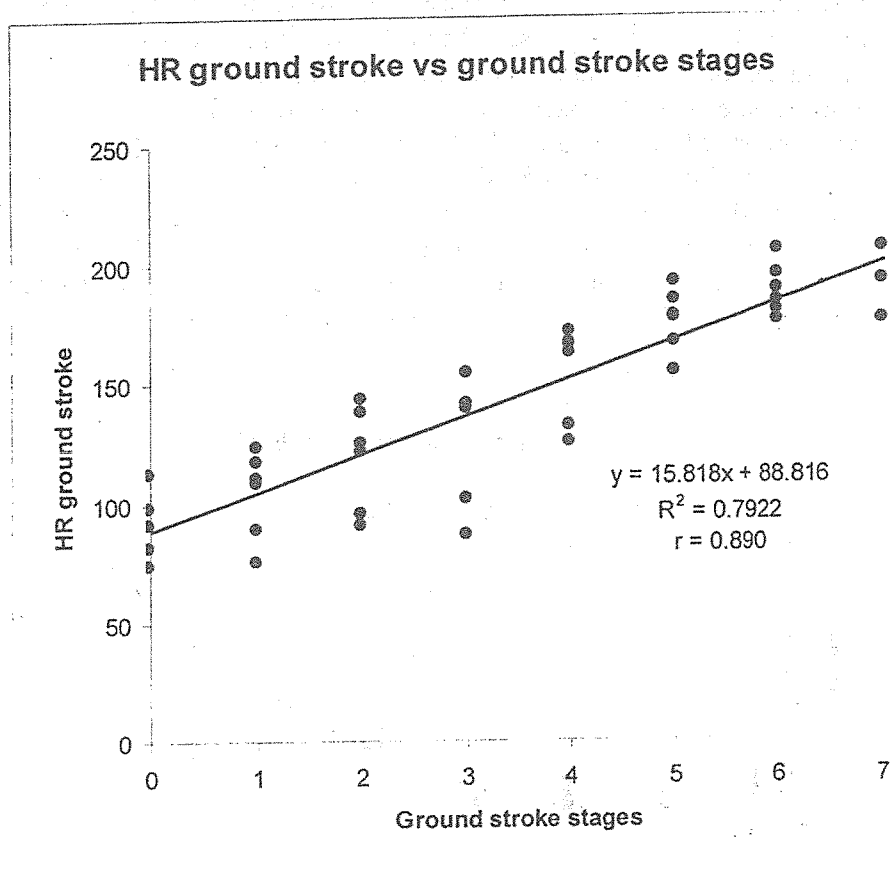


Figure 2

The relationship between HR ground stroke during the ground stroke stages.

Figure 2 represents the correlation between player heart rate responses and ground strokes tennis test stages with the resulting high correlation of 0.89 indicating a graded exercise test which would be very representative of a test performed in a laboratory setting under more highly controlled conditions.

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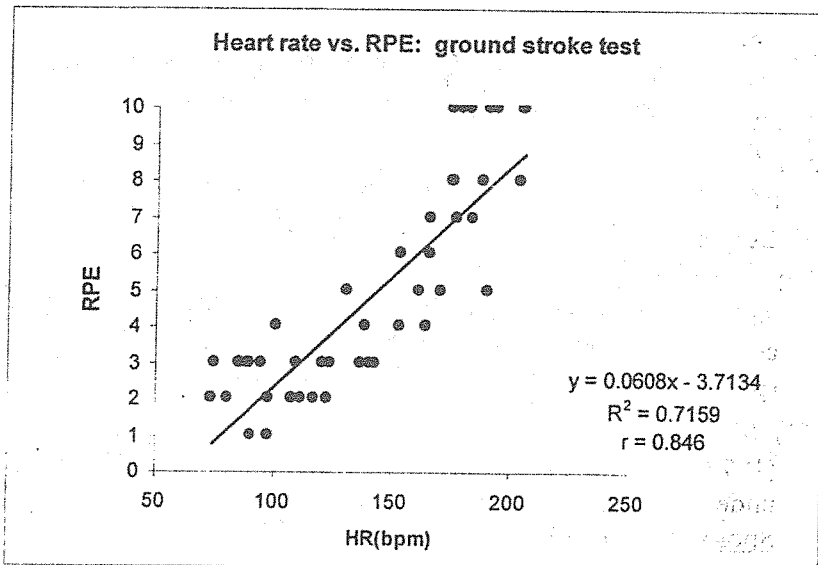


Figure 3

The relationship between RPE in the heart rate (bpm) at ground stroke test.

Figure 3 demonstrates that the players psychological session-RPE responses are highly correlated with the players physiological heart rate responses. Further, the data revealed in Figure 1, 2 and 3 indicate that the ground strokes tennis test developed for this experiment is highly effective for assessing physiological and psychological stress, as well as the ability to maintain tennis skill during gradually increasing physical activity levels.

Conclusions

1. This study was conducted as a preliminary investigation to evaluate the potential of the Borg RPE scale in providing accurate information about the incremental intensity of tennis play, and to develop a practical field test for coaches to use as an alternative to standardized laboratory testing in assessing both physiological and psychological stress of tennis.
2. There was a strong curvilinear relationship in the ground strokes tennis test between stages of the test and error rate when attempting to hit tennis balls to a specific target area. This result suggests that this test can provide coaches with a practical tool to link physiological and, because of the relationship between HR and RPE, psychological stress to sports specific tennis skill.

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