To the Graduate Council:

I am submitting herewith a thesis written by Colin H. Martin entitled "The Effect of Continuous and Intermittent Exercise on Blood and Sweat Lactate Concentrations." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Physical Education.

David R. Bassett, Jr.

David R. Bassett, Major Professor

We have read this thesis
and recommend its acceptance:

Wendy J. Bubb

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THE EFFECT OF CONTINUOUS AND INTERMITTENT EXERCISE ON BLOOD AND SWEAT LACTATE CONCENTRATIONS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Colin Hugh Martin

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A debt of gratitude is offered to my wife, Melanie and my son, Matthew for the sacrifices they have made on my behalf. Their love and understanding have made possible the pursuit of my academic interests.

ABSTRACT

The purpose of this study was to determine if a relationship exists between sweat lactate concentrations and blood lactate concentrations during exercise. Eight males served as subjects for the experimental testing protocol.

All subjects performed continuous exercise on a bicycle ergometer at 60% VO_2 max and intermittent exercise at 100% VO_2 max to create variable blood lactate concentrations. The exercise bouts were 60 minutes in duration and were separated by approximately one week. Measurements of blood lactate were taken at 20, 40, and 60 minutes of exercise and sweat lactate was measured via whole body washdown.

There was no significant difference in sweat lactate concentrations (P = 0.49) between continuous (92.4 +- 34.9 mg/dl) and intermittent exercise (80.9 +- 23.2). Blood lactate concentrations for intermittent exercise (50.0 +- 4.8) was significantly higher (P = 0.0082) than those for the continuous exercise (25.6 +- 3.6). Regression line analysis showed no significant relationship between sweat and blood lactate conentrations (r = .30).

These results indicate that a significant correlation does not exist between sweat lactate concentrations and blood lactate concentrations.

Key Words: Lactate, Continuous, Intermittent, Sweat, Blood, Exertion

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CHAPTER I

INTRODUCTION

Lactic acid production is a result of increased muscular metabolism and glycolytic catabolism. Its formation is dependent on the availability of pyruvate and $NADH^+$ in the presence of the enzyme LDH. However, the removal of lactic acid is also paramount because it has the potential of disrupting cellular homeostasis by decreasing muscle pH. Removal of lactate is thought to occur by two major pathways: 1) oxidation via Kreb's cycle in active skeletal muscle, and 2) reconversion to glucose in the liver (25). However, since lactic acid is found in bodily excretions such as sweat (12, 17, 20), the possibility that lactate removal from the blood may occur via this avenue must be considered.

Although lactic acid concentrations in the sweat have been reported as high as 900 mg/dl (13), little is known about sweat lactate during muscular exercise. Moreover, large variations have been reported (10). These variations might be explained by various collection techniques (14), gender (13), subject's training state (10), heat acclimatization (11), and time of sampling (1). Table 1 summarizes various studies that collected sweat lactate.

TABLE 1. Summary Table for Various Researchers Measuring the Lactic Acid Concentration in Sweat

Reference	Collection Method	Subjects	Collection Time	Exercise Protocol	Values Found (mg/dl)
Lamont (13)	Whole Body Washdown	10 Females	60 min. post-ex.	70% VO_2 max	383 to 903
Weiner (20)		2	Serial Collect. 30 min.	1-2 hrs. ex. "hot room"	66 to 79
Astrand (1)	Regional (Plastic Bags)	2 Males and 2 Females	3 15 min. periods	Mod. Int. on bike 45 min.	160 to 338
Fellmann (10)	Frontal Sweat Collect.	3 Males	Every 5 to 25 min.	60, 87, 90% VO_2 Max	115 to 196
Robinson (17)					36 to 360

The extent to which blood lactate influences sweat lactate has been a topic of investigation. Dill (9) believed that the origin of sweat lactate was unrelated to blood lactate because of the vast differences in concentration between blood and sweat. However, Dill felt that it was peculiar that the sweat gland's metabolism would be anaerobic when blood supply was sufficient. In contrast, Fellmann et al. (10) suggested that high blood lactic acid concentrations, along with increased catecholamines levels in the blood, may act to increase sweat lactate.

The purpose of this study was to determine if the sweat lactate concentration was related to the blood lactate concentration during exercise. Continuous exercise at 60% VO_2 max and intermittent exercise at 100% VO_2 max were used to create variable blood lactate concentrations.

CHAPTER II

METHODS

I. SELECTION OF SUBJECTS

Eight, healthy male subjects participated in the investigation (See Table 2 for physical characteristics of subjects). Signed, informed consent (see Appendix A) and a completed health questionaire (see Appendix B) was obtained in accordance with the University of Tennessee's Committee for Research Participation.

II. PROCEDURES AND TECHNIQUES OF MEASUREMENT

Maximal Oxygen Uptake Test

A preliminary maximal oxygen uptake test was performed on each subject prior to the exercise treatment. This test utilized a calibrated Monark (Model 868) cycle ergometer and was used to determine the exercise load during the exercise treatment. Using a progressive workload with a constant pedal frequency of 80 rpm, the resistance began at 1.0 kg and increased 0.5 kg every minute until the subject was unable to continue. Using Rayfield Biomedical Instrumentation, on-line VO_2, R, and V_E were provided every 60 seconds. Heart rate was measured using a Uniq Heart Watch (Hempstead, New York).

The highest VO_2 value attained was considered the subjects' maximal aerobic power.

Table 2. Physical Characteristics of Subjects

Subject	Age	Weight (kg)	Height (cm)	VO_2 (l/min)
1	23	72.0	177.8	3.89
2	23	75.7	175.3	3.97
3	21	69.6	182.9	2.90
4	19	96.3	177.8	3.27
5	21	80.0	177.8	4.43
6	20	62.4	175.3	3.00
7	36	85.6	175.3	4.52
8	31	67.3	172.7	3.25
M	24.3	76.1	176.9	3.65
SD	6.0	10.9	3.0	0.63

M, mean; SD, standard deviation

Treatment Protocol

Upon arrival at the laboratory the subject was weighed nude to the nearest 0.1 kg. A pre-exercise shower was then taken at the laboratory to remove any sweat or foreign substance that may have accumulated on the skin. All clothing to be worn by the subject during the exercise (bathing suit and socks) and a towel were placed in a plastic bag and pre-weighed to the nearest 0.01 gram. The subject then completed in a counterbalanced order either a continuous or intermittent work bout on a Monark cycle ergometer. Four to five days later the subject returned to the laboratory to complete the remaining work bout.

Both exercise bouts were 60 minutes in duration and the pedal frequency was held constant at 80 rpms (see Appendix C). The continuous bout was performed at 60% of the subjects' maximal aerobic power while the intermittent bout was set at 100% of VO_2 max. The protocol for the intermittent treatment consisted of one minute work intervals interspersed with one minute of rest. The tests were conducted in a room with a temperature ranging from 23.5 to 26.9 degrees Celsius and and 45 to 55 percent relative humidity.

During the exercise treatment, both the investigator, wearing surgical gloves, and subject constantly dried the subject's skin with the pre-weighed towel to avoid sweat loss by runoff. Water intake was allowed but carefully measured. At 20, 40, and 60 minutes of the exercise bout blood samples were taken via finger stick to determine blood lactate.

Following the exercise bout and when sweating had ceased, the subject's clothes and towel were reweighed. The subject then completed the whole body washdown technique which was used to collect sweat samples. These samples were then analyzed for lactate. Finally, the subject provided a post-exercise nude weight.

<u>Whole Body Washdown</u>

The whole body washdown technique described by Lemon and Yarasheski (14) consisted of having the nude subject stand in a small child's wading pool while a known amount of distilled water (3.5 liters) was poured over him. As this was being done the subject scrubbed his entire body to remove any sweat constituents that may have crystallized on the skin. The subject then stepped out and his clothing and towel were placed in the pool. The investigator, wearing surgical gloves, thoroughly rinsed the clothes and towel in the wash water. After the wash water was mixed, a test tube sample was taken to determine the lactate concentration.

Because the lactic acid concentration was measured as a solute, certain considerations were taken into account when calculating the sweat concentration (14).

These included clothing and towel weight change, volume of wash water, total sweat secretion, body weight change, water intake, respiratory water loss (16), and weight loss due to substrate oxidation. For this investigation a computer program (see Appendix D) was created which made the necessary calculations and generated the actual sweat lactic acid concentration.

Blood Sampling

As stated earlier, blood samples via finger stick were taken at 20, 40, and 60 minutes of both exercise bouts. For each sample, approximately 75 uL of blood was mixed with cetrimonium bromide (a cell lysing agent) and sodium fluoride (an antiglycolytic) in a microcentrifuge tube. The tube was then capped and shaken until all contents were mixed and within five minutes the blood sample was analyzed for lactate concentration.

Lactate Analysis

The sweat and blood samples were analyzed for lactate concentrations by the semi-automated Yellow Springs L-Lactate analyzer (Model 27). Using the YSI Syringepet, 25 uL of each sample were injected into the sample chamber. The YSI L-Lactate analyzer was calibrated every third sample against known standards of 5 and 15 mM sodium lactate.

Statistics

A dependent Student's t-test was used to evaluate possible significant differences between sweat samples in continuous and intermittent exercise. Blood lactate concentrations between the exercise bouts were tested for significant differences using an analysis of variance. A two-way repeated measures ANOVA was also used to test for significant differences between the three sample times for blood and Newman-Keuls' post-hoc test identified which treatment and time differed from each other. A simple linear regression equation and Pearson's correlation coefficient was used to examine the relationship between the blood and sweat lactate concentrations during exercise. Comparisons were considered statistically different if the level of probability was <0.05.

CHAPTER III

RESULTS

The means and standard deviations for both sweat and blood lactate for continuous and intermittent exercise are given in Table 3. Table 4 presents the means and standard deviations for the total sweat lactate secretion and sweat rate. These variables were used to determine the sweat lactate concentration (see Appendix D).

No significant difference ($P = 0.49$) was seen in the concentration of sweat lactate between continuous and intermittent exercise (Table E-1, Appendix E). However, as can be seen from Table E-2 (Appendix E), blood lactate concentrations for intermittent work were significantly higher ($P = 0.0082$) than those for continuous exercise (see Figure 1). Blood samples were also significantly different across 20, 40, and 60 minutes of exercise ($P = 0.0227$). However, post-hoc tests (Table E-3, Appendix E) revealed that the 20, 40, and 60 minute blood samples were not significantly different within each exercise bout.

The data were also analyzed to determine if a relationship existed between blood and sweat lactate concentrations (Table E-4 and Table E-5, Appendix E).

The blood lactate concentration in the last 20 minute period of each exercise bout served as the independent variable, and a linear regression equation was obtained to predict the sweat lactate. The slope of the regression line was not significantly different from zero ($P = 0.253$), indicating no relationship between blood and sweat lactate (see Figure 2). The low value shown by Pearson's correlation coefficient (.30) provided further evidence that no relationship existed between blood and sweat lactate.

TABLE 3. Lactic Acid Concentrations (mg/dl) in Sweat and Blood during Continuous and Intermittent Exercise.

Treatment		Sweat	B-20	B-40	B-60
Cont.	M	92.41	29.70	23.14	23.94
	SD	34.94	15.28	10.57	14.77
	SE	12.35	5.40	3.74	5.22
Int.	M	80.89	54.39	50.79	44.94
	SD	23.23	29.29	25.83	22.73
	SE	8.21	10.36	9.13	8.04

B-20, blood sample at 20 minutes; B-40, blood sample at 40 minutes; B-60, blood sample at 60 minutes; Cont, continuous exercise; Int, intermittent exercise; M, mean; SD, standard deviation; SE, standard error

TABLE 4. Total Sweat Lactate Secretion (mg), Sweat Rate (ml/hr), and Sweat Lactate Concentration (mg/dl) in Continuous and Intermittent Exercise

Treatment		Total Sweat Lactate Secretion (mg)	Sweat Rate (ml/hr)	Sweat Lactate Concentration (mg/dl)
Cont.	M	879.65	1068.94	92.41
	SD	224.23	453.15	34.94
Int.	M	1009.72	1242.61	80.89
	SD	509.25	423.63	23.23

Cont, continuous exercise; Int, intermittent exercise; M, mean; SD, standard deviation

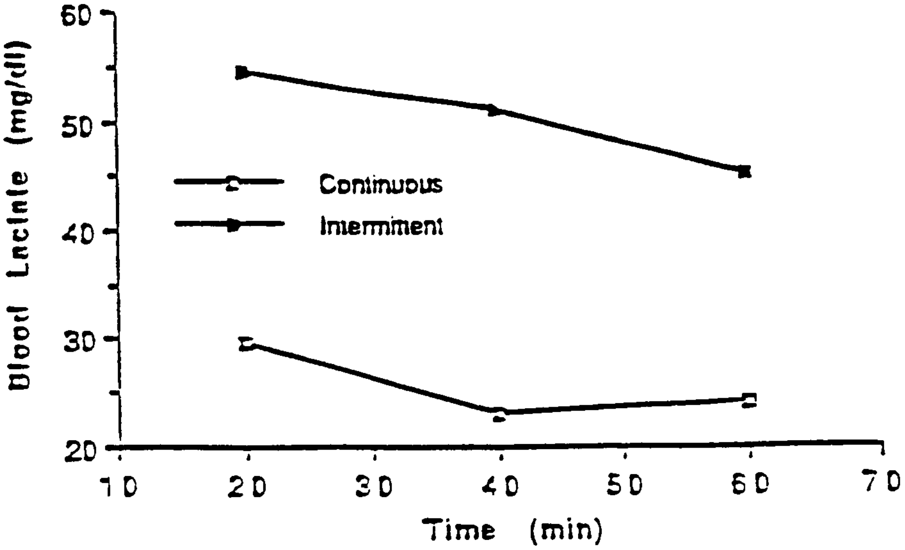

Figure 1. Blood Lactate Concentrations in Continuous and Intermittent Exercise

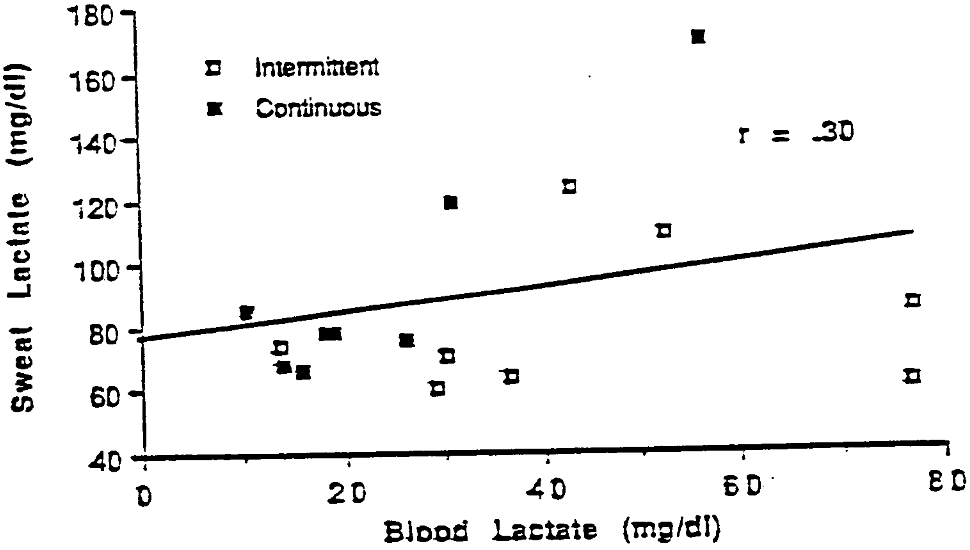

Figure 2. Regression Line Analysis for Sweat and Blood Lactate Concentrations

CHAPTER IV

DISCUSSION

The differentiating effects of continuous and intermittent exercise on blood lactate concentration are well documented (3). Costill (7) demonstrated that marathon runners, working at 70-80 percent of max VO_2, show little or no increase in blood lactate concentration. However, Astrand et al. (2) showed that intermittent exercise can produce blood lactate values as high as 16 mM. In the present investigation both of these findings were supported by the significant difference found in blood lactate concentrations in continuous and intermittent exercise. Although blood lactate values did not reach the high values reported by Astrand, the intermittent exercise did produce values beyond OBLA (onset of blood lactate accumulation) and were two-fold greater than that of the continuous exercise.

The effects that different blood lactate concentrations have on sweat lactate concentrations are controversial. This investigation, in agreement with past researchers (1, 10, 20), found that no relationship existed between blood and sweat lactate. Using continuous and intermittent exercise to bring about variable blood lactate concentrations, sweat lactate concentrations did not significantly differ between the two exercise bouts. However, Fellmann et al. (10) felt that the level of blood lactate does influence sweat lactate concentrations. His conclusion is based on the possibility that increasing levels of blood lactate during incremental work may modify sweat gland excretion to an extent that sweat lactate values are disturbed. Moreover, in his study the most sedentary subject exibited the highest blood and sweat lactate concentrations.

The issue of whether lactic acid in the sweat is taken from the blood by the sweat glands to prevent an excess accumulation of lactate in the tissues and blood has been thoroughly discussed (17, 20). Dill (8, 9) suggested that sweat lactate is a result of glandular metabolism as opposed to being drawn by the blood. This assumption has been supported by the presence of glycogen in the eccrine sweat glands (18) and that its content decreases during exercise (19). Another precursor for released sweat lactate seems to be the level of circulating blood glucose as shown by ^{14}C tracer studies (12).

It is important to note that many investigators do not take special precautions to ensure validity and reliability of their collected sweat data. It is immediately apparent from Table 1 that a large variation exists among available studies. Weiner (20) points out that high sweat lactate values are probably the result of evaporation or sweat collections from enclosed areas of skin. He states that when accounting for these errors, values around 90 mg/dl are normally found for sweat lactate concentrations.

High sweat lactate values can also be found if the sweat collection is taken at the onset of exercise (1, 17). This is attributed to either the initial vasoconstriction of skin blood vessels (1) or the possibility that bacterial and enzymatic action can reduce sweat lactate (4). The present investigation utilized a 60 minute collection period with the lactate analysis not coming until post-exercise. This might explain the lower sweat lactate values compared to researchers (10) who measured the sweat lactate the first 15-30 minutes of exercise.

Other explanations have been given as to why the large variation in sweat lactate data exists. Lamont (13) suggests that gender, with females having higher values, may play a role in sweat lactate concentrations. Other studies point out that physically fit subjects (10,

13) and those that are acclimatized to the heat (9) tend to produce less lactate excretion in the sweat.

Finally, Robinson (17) and Lemon (14) emphasize the importance of choosing the most valid technique for sweat collections. A variety of techniques have been used to collect sweat such as regional collections (arm bag, rubber gloves, filter paper, or gauze) and total body collections (impermeable suits or whole body washdown) (14). Since regional differences exist in sweat constituents (6), the validity of using regional collections should be questioned. Dill (9) found that lactic acid from arm sweat was 1.5 to 3.0 times higher in concentration when collected in an impermeable gauntlet as opposed to the whole body washdown method.

The whole body washdown is probably the most widely used technique. While more accurate and reliable than regional collections (15), the whole body washdown is not without shortcomings. Most notable is the inter- and intra-investigator variability. In addition, sweat loss by runoff can present a problem in very hot and humid enviornments. However, until a more valid and reliable method is introduced, the whole body washdown is considered the method of choice.

In the present investigation no relationship between sweat and blood lactate was observed. Unlike blood lactate which increased two-fold between the continuous and intermittent bouts, sweat lactate showed no significant difference. These findings lead this investigator to conclude that sweat lactate concentrations are independent of blood lactate concentrations. However, data comparisons across studies are difficult because of methodological differences. Further studies surrounding the issue of sweat collection, gender, acclimatization, and glandular physiology need to be undertaken before a definitive statement can be made regarding sweat lactate's relationship to blood lactate.

More specifically, a subsequent study that involved the subject perform two separate but equal exercise bouts (same blood lactate response) could test the reliability of sweat collection methods such as the whole body washdown. A comparison of methods could also be done if one exercise bout utilized a regional sweat collection and the other utilized the whole body washdown method.

To further test the blood and sweat lactate relationship one could have the subjects sit passively in a heating chamber. If the sweat lactate response is similar to that seen in exercise then one could conclude that the sweat lactate is produced solely by the sweat glands and is not drawn from the blood. The effect of gender and fitness level could be studied by having an equal number of physically fit males, sedentary males, physically fit females, and sedentary females perform the tests. The exploration of the above studies would give further insight to sweat collection methodolgy and sweat lactate physiology.

CHAPTER V

CONCLUSIONS

1. Sweat lactate concentrations and blood lactate concentrations are independent of one another.

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APPENDICES

APPENDIX A

INFORMED CONSENT FORM

Investigator: Colin H. Martin

Address:
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School of Education
University of Tennessee-Knoxville
Room 337 HPER

Phone: 615/974-5111

You are invited to participate in a research study, the purpose of which is to examine the effects of submaximal continuous exercise and supermaximal intermittent exercise on lactic acid excretion in the sweat and urine.

If you decide to participate, you will perform a maximal, graded exercise test on a stationary bike ergometer at the beginning of the study. This test will be used to determine the appropriate work loads for the two exercise bouts used in the study The work load will be increased at 2-minute intervals until you are unable to continue. Expired air will be analyzed every second minute of the interval to determine your maximal oxygen consumption. You will have the option of stopping the test at any point. The test will be stopped if symptoms such as excessive shortness of breath or chest discomfort appear.

The procedure for the study will be as follows. First, a shower will be taken in which the subject will wash off with soap and then rinse down tap water and distilled water. After emptying your bladder you will be weighed nude to the nearest gram. This first urine sample will be collected, measured, and analyzed.

The next step will be the continuous exercise bout in which you will exercise for one hour on a stationary bike at 50% max VO_2. During this period the investigator will be drying you with hand towels to avoid sweat loss. After the exercise bout you will reweigh and then position yourself in a child's wading pool, to wash off with distilled water.

The final step will be to collect your post-exercise urine sample. This will be analyzed along with the sweat collected in the washdown for lactate and pH.

After this first lab session, you will come back in approximately one week to perform the exact same procedures as above except that the exercise will consist of high-intensity intermittent bouts instead of the continuous bout. The intermittent exercise will consist of 30 one-minute exercise bouts on a stationary bike at 100% max VO_2. These high intensity one-minute bouts will be interspersed with one minute of rest. During both exercise bouts, blood samples will be taken (finger stick) at 20, 40, and 60 minutes to measure the blood lactate concentration.

The risks involved with exercise include abnormal blood pressure responses, fainting, musculoskeletal injury, disorders of the heart, and in very rare instances heart attack. However, there is only a minor chance that serious complications will occur. In the event that physical injury occurs as a result of this research, the University of Tennessee does not automatically provide reimburesement for medical care or other compensation. If physical injury is suffered in the course of research, or for more information, please notify the project director, Colin Martin, at 974-5111 or the faculty sponsor, Dr. David Bassett, at 974-1284.

The information in this study, such as your aerobic capacity and sweat and urine lactate levels, will be provided to you. Data from this study may be used in research reports or presentations; however, your name and other identity will not be disclosed.

You are free to decide whether or not to participate in this study and are free to withdraw from the study at any time without prejudice.

Before you sign this form please ask questions about any aspects of the study which are unclear to you.

AUTHORIZATION:

I, ______________________________, have read the above and have decided to participate in the research project described above. My signature also indicates that I have received a copy of this consent form.

____

Participant's signature Date

____

Witness Date

Colin Martin
Room 337, HPER Building
615/584-6204

APPENDIX B

PERSONAL HISTORY FORM

Name ______________________________ Age __________

Date ______________________________

Check X if yes:

Past History

Have you ever had?

	Yes	No	Not Sure
Rheumatic fever	( )	( )	( )
Heart murmur	( )	( )	( )
High blood pressure	( )	( )	( )
Any Heart problems	( )	( )	( )
Varicose veins	( )	( )	( )
Lung disease	( )	( )	( )
Epilepsy	( )	( )	( )
Irregular Heart beat	( )	( )	( )
Chronic bronchitis	( )	( )	( )
Emphysema	( )	( )	( )
Diabetes	( )	( )	( )
Bronchial asthma	( )	( )	( )
Kidney disease	( )	( )	( )
Liver disease	( )	( )	( )
Hay fever	( )	( )	( )

Present Symptoms Review:

Have you recently had?

Chest pain	( )
Shortness of breath	( )
Heart palpations	( )
Leg or ankle swelling	( )
Coughing of blood	( )
Hypoglycemia	( )
Feel faint or dizzy	( )

Do you smoke?

How many per day?

For how many years?

How old were you when you started?

In case you have stopped, when did you?

Do you engage in sport-type activities?

What kind?

How often?

Do you have discomfort, shortness of breath, or pain with moderate exercise?

List all medication you are currently taking or have taken within the last month.

Do you have any medical condition not listed here? If so, please describe.

APPENDIX C

TEST PROTOCOL

Exercise Treatment	Duration (min)	Intensity (% VO_2 max)	Speed (RPM)	Physiological Measurement
Continuous	60	60	80	Blood at 20, 40, and 60 min. Sweat
Intermittent	60 *	100	80	Blood at 20, 40, and 60 min. Sweat

* 30 one-minute exercise bouts interspersed with one minute of passive rest

APPENDIX D

COMPUTER PROGRAM (BASIC) FOR DETERMINING SWEAT LACTATE CONCENTRATIONS

```
10  REM MARTIN 6-6-89
20  COLOR 15,6,4
30  CLS:LOCATE 12,14:PRINT"CALCULATIONS FOR DETERMINING
SWEAT LACTATE CONCENTRATIONS"
40  LOCATE 22,65:INPUT"RETURN=>";Z$
50  CLS
60  INPUT"WHAT IS THE SUBJECT'S PRE-EXERCISE BODY-WEIGHT
IN KG ";BW:PRINT
80  INPUT"WHAT WAS THE SUBJECT'S POST-EXERCISE BODY
WEIGHT IN KG ";WB:PRINT
85  LET WL=BW-WB
87  PRINT WL
90  INPUT"WHAT WAS THE SUBJECT'S EXERCISE VO2 IN L/MIN
";VO:PRINT
93  PRINT VO
105 PRINT CAL
107 GOTO 155
110 LET CAL=VO*4.8*60
155 INPUT"WHAT WAS THE SUBJECT'S WATER INTAKE (ML)
";WI:PRINT
160 LET SL=(WL*1000)-(.23*CAL)+WI
165 PRINT SL
170 INPUT"WHAT WAS THE PRE-CLOTHING AND TOWEL WEIGHT IN
GRAMS ";CT:PRINT
180 INPUT"WHAT WAS THE POST-CLOTHING AND TOWEL WEIGHT IN
GRAMS ";POCT:PRINT
190 LET CHA=POCT-CT
195 LET TOT=3500+CHA
197 PRINT TOT
200 INPUT"WHAT WAS THE SWEAT LACTATE AS A SOLUTE
";SS:PRINT
210 LET TSLS=(SS*10)*(TOT/1000)
215 PRINT TSLS
220 LET LAC=TSLS/SL*100
230 PRINT"THE SWEAT LACTATE CONCENTRATION IS "LAC" MG%."
```

APPENDIX E

STATISTICAL ANALYSIS

Table E-1. Dependent Student's t-test for Sweat Lactate Concentration between Continuous and Intermittent Exercise

VARIABLE	MEAN	STD ERROR OF MEAN	T	PR>T
DIFF	11.53	15.77	0.73	0.4886

Table E-2. Repeated Measures ANOVA for Blood Lactate Concentration between Continuous and Intermittent Exercise

SOURCE	DF	SUM OF SQUARES	F	P
SUBJECTS	7	12541.01		
EXERCISE	1	7171.19	13.282	.0082
ERROR	7	3779.55		
TIME	2	480.27	5.019	.0227
ERROR	14	669.88		

Table E-3. Newman-Keuls Post-Hoc Summary Table for Blood Lactate Concentration

			A	B	C	D	E	F
A.	CONT	40 MIN *	X	-	-	S	S	S
B.	CONT	60 MIN	-	X	-	S	S	S
C.	CONT	20 MIN	-	-	X	S	S	S
D.	INT	60 MIN	S	S	S	X	-	-
E.	INT	40 MIN	S	S	S	-	X	-
F.	INT	20 MIN	S	S	S	-	-	X

CONT, continuous exercise; INT, intermittent exercise;
S, significant difference
* Data are ordered from the lowest to the highest value

Table E-4. Linear Regression Analysis for Sweat and Blood Lactate Concentrations

VARIABLE NAME	COEFFICIENT	STD. ERR. ESTIMATE	T STATISTIC	PROB>T
CONSTANT	72.38	13.97	5.18	0.000
BLOOD	0.4144	0.3474	1.19	0.253

Table E-5. Pearson's Correlation Coefficient for Sweat and Blood Lactate Concentrations

CORRELATION COEFFICIENT	T	DF	P
.3038	1.19	14	.2527

APPENDIX F

INDIVIDUAL SUBJECT DATA

SUBJECT	TREATMENT	BLOOD (mg/dl) 20	40	60	SWEAT (mg/dl)
1	Cont	11.0	11.1	10.5	85.0
	Int	23.6	29.5	29.2	60.7
2	Cont	22.5	15.3	19.1	78.4
	Int	33.9	33.2	30.3	70.6
3	Cont	39.9	31.4	26.3	75.7
	Int	79.9	76.2	76.8	61.5
4	Cont	28.0	26.6	31.1	119.3
	Int	84.9	54.9	52.6	108.8
5	Cont	53.3	23.9	18.1	78.1
	Int	90.2	93.9	77.1	85.0
6	Cont	46.8	43.4	56.6	168.6
	Int	68.9	63.1	36.7	64.0
7	Cont	16.3	17.5	15.9	66.0
	Int	22.0	18.4	13.7	73.7
8	Cont	19.8	15.9	13.9	68.2
	Int	31.7	37.1	43.1	122.8

Cont, continuous exercise; Int, intermittent exercise

VITA

Colin Hugh Martin was born in Florence, Alabama on June 8, 1966. He attended public schools in Russellville, Alabama and was graduated from Russellville High School in June 1984. He entered the University of Alabama in September of that year and received a Bachelor of Science degree in Health and Physical Education from that institution in May 1988.

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