Strong point on Lance' high economy!

ECONOMY CALCULATIONS - MEN CYCLISTS
SENIOR CAMP _HUNT TEXAS (FEB 91)

SUBJECT	CAMP	TRIAL (#)	PACE (W)	VO2 ml/kg	W/LBM REGVO ml/kg	DIFF	COEF	ECONO INDEX	INDEX
Armstrong	02/27/9	1	150	33	31.1	1.9	1.56	0	0.00
Armstrong	02/27/9	2	200	39.4	38.2	1.2		0	
Armstrong	02/27/9	3	250	46.8	45.3	1.5		0	
Armstrong	02/27/9	4	300	52.8	52.4	0.4		0	
Armstrong	02/27/9	5	325	58.2	55.9	2.3		0	
Armstrong	02/27/9	6	350	61.3	59.4	1.9		0	
Armstrong	02/27/9	7	375	64.6	63.0	1.6		0	
[redacted]	02/27/9	1	150	37.1	33.9	3.2	3.29	0	0.00
[redacted]	02/27/9	2	200	45.1	41.9	3.2		0	
[redacted]	02/27/9	3	225	47.8	45.9	1.9		0	
[redacted]	02/27/9	4	250	54	49.9	4.1		0	
[redacted]	02/27/9	5	275	57	53.9	3.1		0	
[redacted]	02/27/9	6	300	61	57.9	3.1		0	
[redacted]	02/27/9	7	325	63.4	61.9	1.5		0	
[redacted]	02/27/9	8	350	72.1	65.9	6.2		0	
[redacted]	02/27/9	1	150	33	34.0	-1.0	-0.75	1	0.75
[redacted]	02/27/9	2	200	40.3	42.1	-1.8		1	
[redacted]	02/27/9	3	250	48.9	50.2	-1.3		1	
[redacted]	02/27/9	4	275	53	54.2	-1.2		1	
[redacted]	02/27/9	5	300	57	58.2	-1.2		1	
[redacted]	02/27/9	6	325	63	62.3	0.7		0	
[redacted]	02/27/9	7	350	66	66.3	-0.3		1	
[redacted]	02/27/9	8	375	70.5	70.4	0.1		0	
[redacted]	02/27/9	1	150	33.9	34.1	-0.2	-0.06	1	0.43
[redacted]	02/27/9	2	200	38.4	42.2	-3.8		1	
[redacted]	02/27/9	3	250	49.9	50.3	-0.4		1	
[redacted]	02/27/9	4	275	54.6	54.3	0.3		0	
[redacted]	02/27/9	5	300	58.5	58.4	0.1		0	
[redacted]	02/27/9	6	325	64.5	62.4	2.1		0	
[redacted]	02/27/9	7	350	67.9	66.5	1.4		0	
[redacted]	02/27/9	1	150	34.9	33.5	1.4	0.73	0	0.33
[redacted]	02/27/9	2	200	42.9	41.4	1.5		0	
[redacted]	02/27/9	3	250	51.1	49.3	1.8		0	
[redacted]	02/27/9	4	275	54.9	53.2	1.7		0	
[redacted]	02/27/9	5	300	56.2	57.2	-1.0		1	
[redacted]	02/27/9	6	325	60	61.1	-1.1		1	

EXHIBIT
118
Claimant
PENGAD 800-631-6989

[redacted]

	NAME	SEX	TEAM	WGHT (KG)	BFAT%	SSKF (MM)	VO2MAX (ML/KG)	HR (BPM)	LA MAX
1	ARMSTRONG	M	A	80.5	5.8	50.3	77.0	200	5.7
[redacted]	[redacted]	M	B	83.6	8.6	58.3	66.2	192	6.0
[redacted]	[redacted]	M	A	70.5	5.6	49.4	73.0	195	7.8
[redacted]	[redacted]	M	A	68.9	3.4	34.7	78.0	197	7.8
[redacted]	[redacted]	M	A	72.7	8.7	62.7	72.5	199	6.3
[redacted]	[redacted]	M	B	74.1	8.1	60.0	75.3	192	4.8
[redacted]	[redacted]	M	A	63.9	4.6	43.1	78.2	203	6.6
[redacted]	[redacted]	M	A	72.5	6.2	46.8	68.7	195	6.6
[redacted]	[redacted]	M	B	67.7	7.8	55.8	67.3	184	7.8
[redacted]	[redacted]	M	A	71.4	7.1	51.0	75.0	193	6.3
[redacted]	[redacted]	M	A	84.0	9.1	66.1	75.5	188	9.0
[redacted]	[redacted]	M	A	66.6	6.1	52.9	79.5	214	9.0
[redacted]	[redacted]	M	A	67.5	6.5	53.4	74.5	194	9.0
[redacted]	[redacted]	M	A	80.5	•	•	70.1	184	8.4
[redacted]	[redacted]	F	B	61.8	16.8	75.9	64.7	184	6.3
[redacted]	[redacted]	F	A	63.4	17.8	83.5	58.3	204	8.7
[redacted]	[redacted]	F	B	63.0	13.1	56.9	64.5	184	6.9
[redacted]	[redacted]	F	A	56.6	13.4	58.7	68.8	185	6.3
[redacted]	[redacted]	F	A	60.7	11.4	49.7	69.8	190	9.0
[redacted]	[redacted]	F	A	61.0	14.9	69.0	56.7	191	8.4
[redacted]	[redacted]	F	A	59.8	13.4	57.8	65.2	201	6.9
[redacted]	[redacted]	F	B	57.7	17.7	83.4	64.5	180	9.3
[redacted]	[redacted]	F	B	60.2	16.6	79.4	57.2	186	9.6
[redacted]	[redacted]	F	A	60.9	19.6	94.0	61.5	192	7.8
[redacted]	[redacted]	F	B	47.3	14.6	65.7	65.5	188	5.4
[redacted]	[redacted]	F	A	63.6	12.1	51.8	59.2	192	8.1
[redacted]	[redacted]	F	A	58.4	11.5	47.7	64.0	187	7.8
[redacted]	[redacted]	F	A	59.1	18.4	88.0	65.1	174	8.4
[redacted]	[redacted]	F	A	58.6	11.7	50.3	65.2	189	6.9
[redacted]	[redacted]	F	A	52.5	13.6	58.7	69.0	197	7.2

	WATT MAX	W MAX/KG	W@LT	%W.MAX@LT	HR@LT	%HR.MAX@LT	VO2@LT	%VO2MAX@LT
1	500	6.2	315	63.0	161	80.5	55.5	72.1
2	450	5.4	300	66.7	150	78.1	50.2	75.8
3	475	6.7	280	58.9	166	85.1	57.0	78.1
4	500	7.3	280	56.0	150	76.1	54.0	69.2
5	450	6.2	275	61.1	165	82.9	54.5	75.2
6	450	6.1	275	61.1	161	83.9	54.9	72.9
7	450	7.0	250	55.6	170	83.7	58.0	74.2
8	475	6.6	265	55.8	152	77.9	50.5	73.5
9	425	6.3	275	64.7	166	90.2	55.6	82.6
10	475	6.7	290	61.1	150	77.7	54.5	72.7
11	500	6.0	280	56.0	154	81.9	48.5	64.2
12	475	7.1	285	60.0	180	84.1	58.0	73.0
13	450	6.7	275	61.1	170	87.6	57.0	76.5
14	475	5.9	255	53.7	147	79.9	46.5	66.3
15	350	5.7	180	51.4	144	78.3	42.5	65.7
16	350	5.5	180	51.4	161	78.9	40.5	69.5
17	375	6.0	220	58.7	150	81.5	50.0	77.5
18	350	6.2	215	61.4	150	81.1	49.5	71.9
19	375	6.2	195	52.0	154	81.1	46.0	65.9
20	325	5.3	190	58.5	167	87.4	44.5	78.5
21	375	6.3	180	48.0	161	80.1	44.5	68.3
22	350	6.1	205	58.6	154	85.6	50.5	78.3
23	350	5.8	205	58.6	165	88.7	48.0	83.9
24	375	6.2	245	65.3	172	89.6	53.0	86.2
25	275	5.8	175	63.6	168	89.4	55.5	84.7
26	350	5.5	210	60.0	170	88.5	48.0	81.1
27	350	6.0	180	51.4	143	76.5	42.0	65.6
28	350	5.9	170	48.6	143	82.2	46.0	70.7
29	350	6.0	220	62.9	160	84.7	52.0	79.8
30	350	6.7	200	57.1	173	87.8	55.6	80.6

	W@MSS	%W.MAX@MSS	HR@MSS	%HR.MAX@MSS	VO2@MSS	%VO2MAX@MSS	HR in TT
1	340	68.0	169	84.5	59.0	76.6	•
2	390	86.7	185	96.4	60.0	90.6	158
3	345	72.6	180	92.3	68.0	93.2	190
4	350	70.0	165	83.8	65.0	83.3	173
5	345	76.7	185	93.0	66.0	91.0	164
6	300	66.7	167	87.0	56.2	74.6	170
7	320	71.1	194	95.6	72.0	92.1	•
8	310	65.3	167	85.6	57.5	83.7	169
9	290	68.2	169	91.8	58.0	86.2	•
10	340	71.6	166	86.0	63.5	84.7	161
11	360	72.0	170	90.4	60.0	79.5	•
12	340	71.6	194	90.7	67.0	84.3	•
13	320	71.1	180	92.8	69.5	93.3	185
14	330	69.5	170	92.4	60.0	85.6	158
15	210	60.0	158	85.9	48.0	74.2	171
16	240	68.6	187	91.7	51.0	87.5	190
17	260	69.3	165	89.7	55.5	86.0	167
18	235	67.1	163	88.1	53.5	77.8	180
19	250	66.7	172	90.5	57.2	81.9	173
20	230	70.8	183	95.8	52.0	91.7	•
21	240	64.0	182	90.5	56.0	85.9	174
22	250	71.4	165	91.7	55.3	85.7	•
23	230	65.7	172	92.5	52.0	90.9	•
24	275	73.3	181	94.3	57.6	93.7	•
25	195	70.9	173	92.0	61.0	93.1	180
26	240	68.6	180	93.8	53.0	89.5	184
27	250	71.4	175	93.6	56.0	87.5	•
28	210	60.0	157	90.2	53.5	82.2	155
29	260	74.3	175	92.6	59.0	90.5	177
30	220	62.9	177	89.8	59.5	86.2	186

ent Report

27-Jun-1991 7:51

PIKES PEAK DIAGNOSTIC SERVICE, INC.
325 E. FONTANERO SUITE 102
COLORADO SPRINGS, COLORADO 80907
719-634-0101

46.7 HcT
16.1

Patient: ARMSTRONG, LANCE
Cup Number: C6 Request Number: 86

Comments: USOTC/ USA CYCLING
COLLECTED 6/24/91 TIME C
FASTING

1991 Data

Test	Result	Fla		
Profile: BIOCHEM				
Total Protein	7.6 G/DL			?.3
Albumin	5.0 G/DL			?.3
Globulin	2.6 G/DL			.4
ALB\GLOB	1.9 RATIO			?.2
Calcium	9.7 MG/DL		8.3	10.8
Phosphorus	3.6 MG/DL		2.5	5.5
Glucose	78. MG/DL		65.	110.
BUN	21. MG/DL		7.	28.
Creatinine	1.1 MG/DL		0.4	1.5
Uric Acid	5.6 MG/DL		3.8	7.8
Total Bili.	1.0 MG/DL		0.1	1.5
Alk. Phos	61. U/L		37.	147.
AST/SGOT	23. U/L		12.	36.
ALT/SGPT	19. U/L		4.	36.
LDH-L	151. U/L		89.	221.
GGT	17. U/L		0.	50.
Cholesterol	169. MG/DL		140.	220.
Triglycerides	91. MG/DL		35.	160.
Sodium	141.8 mEQ/L		135.0	148.0
Potassium	4.33 mEQ/L		3.50	5.30
Chloride	103. mEQ/L		96.	112.
Carbon Dioxide	26.2 mEQ/L		19.0	29.0
Iron	126. UG/DL		50.	150.
Profile: IRON				
Iron	126. UG/DL		50.	150.
TIBC	300.0 UG/DL		250.0	350.0
SATURATION	42.0 PERCENT		16.0	42.0
Tests:				
FERRITIN	73.8 NG/ML		25.0	178.0

Patient Report

27-Jun-1991 7:21

PIKES PEAK DIAGNOSTIC SERVICE, INC.
325 E. FONTANERO SUITE 102
COLORADO SPRINGS, COLORADO 80907
719-634-0101

Patient: ARMSTRONG, LANCE ID: 11314
Cup Number: C1 Request Number: 81 Age: 19 Sex: M

Comments: USOTC/ USA CYCLING
COLLECTED 6/24/91 TIME 0700
FASTING

Test	Result	Flags	Low	High
Profile: CBC				
WHITE BLOOD CT	7.90 THOUSAND		4.40	11.00
RED BLOOD CT	4.79 MILLION		4.20	6.00
HEMOGLOBIN	16.1 GRAMS		12.6	17.5
HEMOTOCRIT	46.7 %		36.0	50.0
MCV	95.5 fL		80.0	99.0
MCH	32.8 PG		27.0	33.0
MCHC	35.2 G/DL		30.0	37.0
Profile: DIFF				
NEUTROPHILS	49. %	BELOW NORM	50.	72.
NEUT BANDS	3. %		0.	5.
LYMPHOCYTES	43. %	ABOVE NORM	20.	40.
MONOCYTES	6. %		1.	6.
BASOPHILES	0. %		0.	2.
Tests:				
PLATELETS	307. THOUSAND		150.	450.
RETIC CT	0.9 PERCENT		0.5	1.5
HAPTOGLOBIN	66.2 MG/DL		50.0	320.0

UNITED STATES CYCLING FEDERATION

CYCLING SPORTS SCIENCE TESTING

Success as a cyclist is a result of a complex blend of many factors- genetic endowment, health and nutrition, suitability and amount of training, technique and skill, mental preparation and attitude, and even luck! The purpose of sports science is to apply science, technology and medicine to the analysis and improvement of athletic performance. Testing is used to assess parameters that influence your performanc. It can provide you with objective information about your physiological, biomechanical and psychological characteristics and how they affect your cycling capabilities. We are here to help you understand these results and use them in conjuction with your coaches to develop, evaluate and modify training regimens, technique and equipment. The information provided can help you minimize the impact of your weaknesses while optimally utilizing your strengths. Testing is most beneficial when it is done on a regular basis to monitor changes.

Here are your test results, along with explanations. If you have any questions, feel free to ask any time. I enjoyed working with each of you and wish you luck in '92.

Tailwinds,

Pam

Pamela J. Stevenson,
U.S. National Cycling Team Sports Scientist

LIST OF TESTS

1. Blood Test
2. Body Composition
3. VO_2 Submax & Max
4. Vertical Jump
5. Wingate
6. Cybex
7. Biomechanics (to be included later)
8. Pulmonary Function
9. Flexibility (to be included later)

In addition, these examinations were performed:

Medical
Vision
Dental

BLOOD TEST

Blood tests are used to describe the balance of constituents which are released into and taken up from the blood by the various organs and tissues of the body. Analysis of blood can aid in the diagnosis of disease, injury, nutritional deficiencies or other abnormal functioning of the body. In an otherwise healthy athlete, blood analysis may be used for the evaluation of effects of conditioning or as a screening tool for detection of overtraining. Samples are obtained in a rested, fasted state so that constituents are at a baseline level. Levels of some blood variables may be altered for several days following intense or prolonged exercise.

The usual screening packages we perform on cyclists include Complete Blood Count (CBC), Biochemistry Profile (SMAC) and Iron Profiles. Any of your values that fall outside a normal range are flagged. Your physician can counsel you about these.

Patient Report

7-Dec-1991 8:57

PIKES PEAK DIAGNOSTIC SERVICE, INC.
325 E. FONTANERO SUITE 102
COLORADO SPRINGS, COLORADO 80907
719-634-0101

Patient: ARMSTRONG, LANCE — ID: 21974
Cup Number: D10 — Request Number: 131 — Age: 20 — Sex: M

Comments: USA CYCLING TEAM
COLLECTED 12/6/91 TIME 0700
FASTING

Test	Result	Flags	Low	High
Profile: BIOCHEM				
Total Protein	7.6 G/DL		6.0	8.3
Albumin	4.1 G/DL		3.5	5.3
Globulin	3.5 G/DL	ABOVE NORM	2.0	3.4
ALB\GLOB	1.2 RATIO		1.0	2.2
Calcium	9.8 MG/DL		8.3	10.8
Phosphorus	4.5 MG/DL		2.5	5.5
Glucose	86. MG/DL		65.	110.
BUN	21. MG/DL		7.	28.
Creatinine	1.3 MG/DL		0.4	1.5
Uric Acid	7.5 MG/DL		3.8	7.8
Total Bili.	0.5 MG/DL		0.1	1.5
Alk. Phos	69. U/L		37.	147.
AST/SGOT	31. U/L		12.	36.
ALT/SGPT	24. U/L		4.	36.
LDH-L	185. U/L		89.	221.
GGT	28. U/L		0.	50.
Cholesterol	194. MG/DL		140.	220.
Triglycerides	198. MG/DL	ABOVE NORM	35.	160.
Sodium	142.9 mEQ/L		135.0	148.0
Potassium	4.50 mEQ/L		3.50	5.30
Chloride	102. mEQ/L		96.	112.
Carbon Dioxide	25.3 mEQ/L		19.0	29.0
Profile: LIPIDS				
Cholesterol	194. MG/DL		140.	220.
Triglycerides	198. MG/DL	ABOVE NORM	35.	160.
HDL Cholesterol	46. MG/DL		30.	85.
LDL	108. MG/DL		62.	178.
CARDIAC RISK	4.22		2.40	7.30
Tests:				
Creatine Kinase	71. U/L		26.	174.
Magnesium	1.75 mEq/L		1.40	2.30
T-4	7.1 UG/DL		4.5	11.5

Patient Report

7-Dec-1991 10:47

PIKES PEAK DIAGNOSTIC SERVICE, INC.
325 E. FONTANERO SUITE 102
COLORADO SPRINGS, COLORADO 80907
719-634-0101

Patient: ARMSTRONG, LANCE ID: 21974
Cup Number: E2 Request Number: 163 Age: 20 Sex: M

Comments: USA CYCLING TEAM
COLLECTED 12/6/91 TIME 0700
FASTING

Test	Result	Flags	Low	High
Profile: CBC				
WHITE BLOOD CT	7.10 THOUSAND		4.40	11.00
RED BLOOD CT	5.24 MILLION		4.20	6.00
HEMOGLOBIN	16.8 GRAMS		12.6	17.5
HEMOTOCRIT	48.8 %		36.0	50.0
MCV	96.2 fL		80.0	99.0
MCH	32.1 PG		27.0	33.0
MCHC	33.3 G/DL		30.0	37.0
Profile: DIFF				
NEUTROPHILS	52. %		50.	72.
NEUT BANDS	5. %		0.	5.
LYMPHOCYTES	39. %		20.	40.
MONOCYTES	4. %		1.	6.
EOSINOPHILS	0. %		0.	4.
BASOPHILES	0. %		0.	2.
Profile: IRON				
IRON, Serum	102.0 UG/DL		50.0	150.0
TIBC	288.0 UG/DL		250.0	350.0
SATURATION	35.4 PERCENT		16.0	42.0
FERRITIN	167.1 NG/ML		25.0	178.0
Tests:				
PLATELETS	355. THOUSAND		150.	450.

BODY COMPOSITION

Many athletes use body weight as a measure of fitness, but body composition is a better indicator of your health and fitness status. The body can be viewed as having two components: lean tissue and fat tissue. Lean tissue is basically all non-fat tissue and includes muscle, bone, internal organs and connective tissue.

A certain amount of fat tissue is essential to maintain health. The rest, called storage fat, is an energy reserve stored in those unfriendly bulges. When you consume more calories than you expend, the excess are stored as fat.

Fat weight is usually expressed as a percentage of your total body weight. The average man is about 3% essential fat and 15% fat overall. The average woman is about 12% essential fat and 25% fat overall. The difference is due to the need for protection of reproductive organs in the female.

There are several methods for assessing body composition. The most common include skinfold measurement, underwater weighing and electrical impedance. Underwater weighing is usually considered most accurate, but large errors can often occur because people have difficulty exhaling fully underwater. Also, the method is complicated and time-consuming. Electrical impedance is generally considered unreliable because results depend heavily upon your state of hydration. We use use skinfold calipers because accurate results can be obtained simply and quickly. The thickness of your fat layer is measured in millimeters at seven sites. You can track the "sum of seven" as an indicator of your body fatness. These results are also plugged into equations that estimate your percent body fat. Remember that is just an **estimate** and may be off by 2 or 3 percent! Repeated measurements done in a consistent fashion over time can be useful for monitoring changes in your body composition brought on by your training and diet.

What is a desirable level of body fatness for cyclists? Most storage fat is simply excess baggage to be carried up the hills, but too little fat can also impair performance by increasing susceptibility to illness. U.S. National Team male cyclists average 7% body fat while females average 15% body fat.

You can calculate your desired body weight from your current percent fat if you have a target percent body fat (X):

$$\text{Desired Weight} = \frac{\text{Current Weight} * (1 - \text{Current \% fat})}{(1-X)}$$

Body Composition
Averages for U.S. National Cycling Team

	Sr. Men	Sr. Women
Age (years)	22.5	25.0
Height (cm)	180.7	169.7
Weight (Kg)	76.1	59.7
Percent Body Fat	6.45	13.57

UNITED STATES OLYMPIC COMMITTEE
SPORTS PHYSIOLOGY LABORATORY
COLORADO SPRINGS, COLORADO

NAME: Lance Armstrong
AGE: 20.0 years
SEX: Male
WEIGHT: 80.2 kg
HEIGHT: 180.3

DATE: 12/6/1991
SPORT: 16
TESTED BY: ps

*** BODY COMPOSITION : 7 SITE SKINFOLD TEST ***

SITE	YOUR AVERAGE
CHEST	6.2
AXILLA	6.0
TRICEPS	5.5
SUBSCAPULAR	10.5
ABDOMINAL	10.8
SUPRAILIUM	8.6
THIGH	7.0
TOTAL	54.6

PERSONAL DATA

BODY DENSITY: 1.0841
% BODY FAT: 6.59
WEIGHT OF BODY FAT: 5.29 kg
FAT FREE WEIGHT: 74.91 kg
SUM OF SKINFOLDS: 54.6 mm

Reference:

A.S. Jackson et al., 'Generalized Equations for Prediciting Body Density of Women', Medicine and Science in Sports, 1980.

A.S. Jackson and M. L. Pollack, 'Generalized Equation for Predicting Body Density of Men', British Journal of Nutrition, 40(1978):497-504.

OXYGEN CONSUMPTION, BLOOD LACTATE, AND ECONOMY

VO2max represents the maximum amount of oxygen that can be delivered to and used by the muscles. While it is an important indicator of success for a cyclist, it is by no means the only, nor necessarily the most important determinant of success, especially among a group of elite cyclists. The highest value of VO2max is usually achieved after the initial few years of intense training, and then fluctuates throughout a season as the amount and/or specificity of training changes. For example, during winter, the training emphasis shifts to alternate forms of training including weight training. Since cycling-specific training and the general amount of training are reduced, the VO2max tends to decrease during this time. VO2max may be decreased due to fatigue after a period of intense training and/or competition. Also, VO2max measured at altitude may be 5 - 10% lower than a VO2max measured at sea-level. VO2max can be improved best by training at the VO2max intensity, an all-out effort that can be sustained for about 5 minutes. Improvements to VO2max also result from an increase in the overall volume of training.

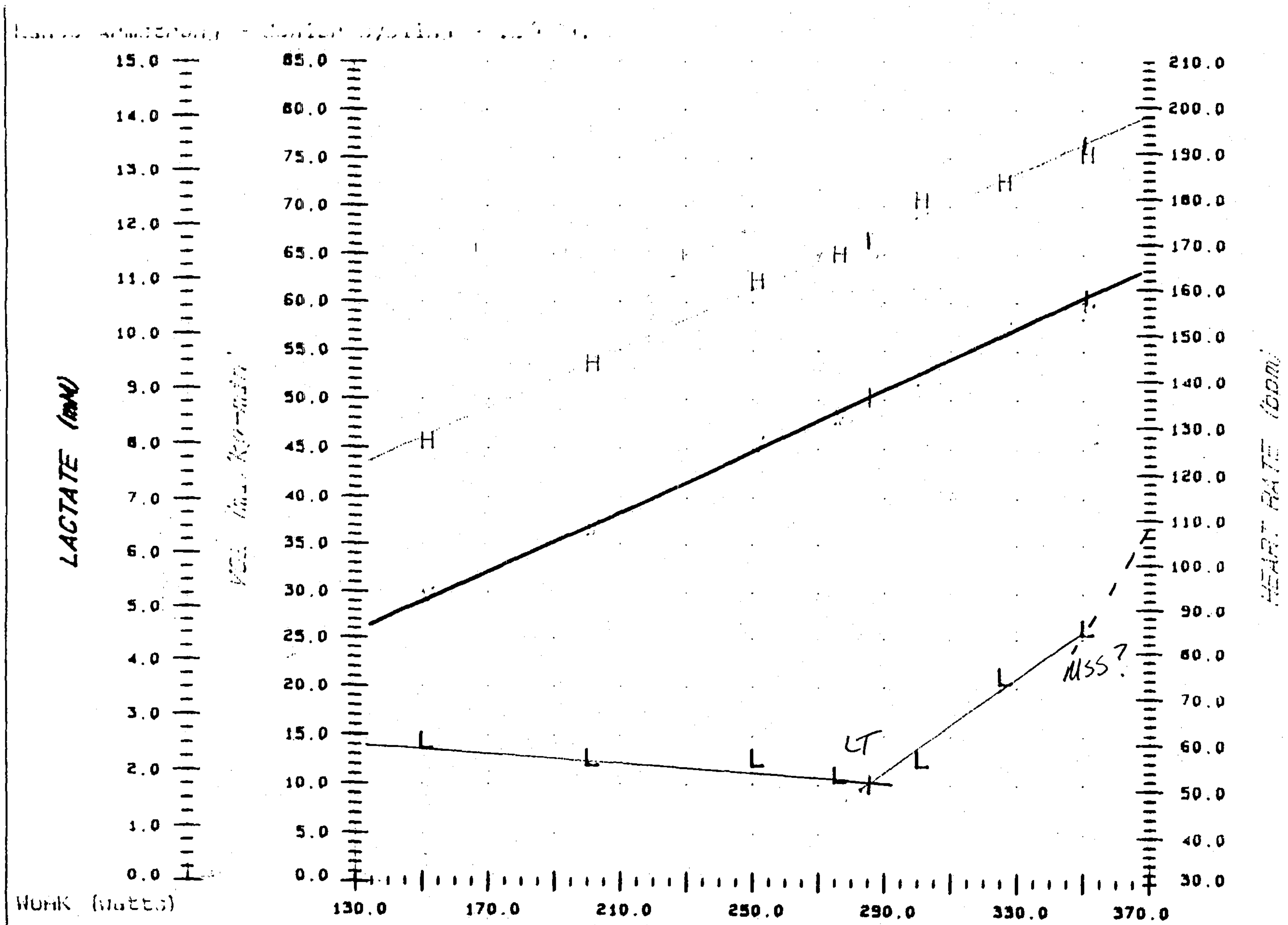
Other values associated with VO2max are maximum watts (Wmax), maximum heart rate (HRmax), and maximum lactate (LAmax). Wmax, as measured in this test, represents the maximum power that can be produced <u>aerobically</u>; that is why the watts are increased slowly, 25W/min. It is important to evaluate VO2max in terms of Wmax. Ideally, a high VO2max should occur at a high Wmax (W/kg) Training can cause an increase in Wmax with or without an increase in VO2max. Unfortunately, Wmax is often overlooked when testing cyclists. Comparison of cyclists' power (aerobic or anaerobic) should be done on a Watts/kilogram basis.

Maximum heart rate is primarily determined by genetics and affected by age. HRmax values show considerable individual differences among even trained individuals. We have seen maximum heart rates above 220 and as low as 175 bpm. Training may either <u>minimally</u> increase or decrease HRmax. However, training generally lowers heart rate at any given submaximum pace. Heart rate response to exercise is very individualistic, it can be used to monitor the acute stress of a specific training intensity or determine the cumulative effect of a period of training. Worsening heart rate responses to submaximum intensities may also be a useful warning of overtraining.

Lactate levels in the blood are a balance between lactate production (i.e. anaerobic energy processes) and lactate removal (i.e. aerobic energy processes). At exercise intensities below lactate threshold, removal is greater than production, and blood lactate levels are at or near resting levels. As the intensity increases above the threshold, production becomes greater than removal, and blood lactate levels increase above resting. LAmax represents the anaerobic contribution to the total energy production at the point of maximum oxygen consumption. In this test, we were concerned with lactate production below and at VO2max. It is possible to perform work at intensities greater than VO2max for short periods of time (sprints and short intervals), and there are other tests, such as the Wingate Test, which can measure your performance (watts, lactate, heart rate) at these supermaximum intensities. The value of LAmax is affected by the type of training and diet. Sprint-type training increases the ability for anaerobic energy (and lactate) production, as well as increasing the ability to tolerate high levels of lactate. Distance and threshold training, on the other hand, increase the ability to remove lactate. Your value for LAmax may be the result of the type of training you have been emphasizing. A high carbohydrate diet is important not only for endurance performance, but also for sprint performance, since carbohydrate is the only fuel "burned" anaerobically. Low LAmax values may also reflect a carbohydrate deficiency.

Regardless of the of the mystique attached to VO2max, a more important predictor of performance in steady-state events (e.g. marathons, cross-country ski races, time trials) is the percent of VO2max that can maintained for the duration of the race. This percentage can be related to a blood lactate level, either a "threshold" - the abrupt increase in resting lactate, or a fixed concentration such as 4 millimoles/liter (mM). Different reports on endurance performance offer different views as to whether the intensity at the lactate breakpoint threshold (LT) or at the fixed 4-mM lactate level is better related to successful performance. Europeans feel that the 4-mM lactate intensity is the maximum intensity that can be maintained for about an hour (max steady state - MSS), that it represents a limit to prolonged tolerance of lactate "burn". This was based on studies of marathon runners and nordic skiers. However, there are individual differences in lactate production, removal, and tolerance, and lactate levels as high as 7 mM have been found after similar long steady pace runs. Other studies have usually seen lactate levels of 3 - 5 mM after marathons, and marathon-pace runs. While the lactate threshold may be related to performance, the intensity (in terms of speed, watts, or HR) at which this threshold/breakpoint occurs may be lower than what actually occurs in a time trial. Thus, the lactate threshold intensity may represent a minimum intensity for threshold or tempo training. The fixed 4-mM or individual MSS intensity, on the other hand, may be closer to the actual intensity occuring during time-trial competition. Improvements in threshold or 4 mM pace come from training at those intensities. Before his historical hour record, much of Moser's training was at an MSS level. A typical value related to lactate is 81.5 %VO2max at LT for a group of American senior cyclists.

Another physiological variable which affects cycling success is economy. It is a measure of the aerobic demand of cycling - how much oxygen is required to go a certain speed or produce a certain power output (as in this test). The cyclist who can achieve that speed using the lower amount of oxygen may have a competitive advantage. Economy can be affected by various factors such as age, weight, the environment, position on the bike, pedalling style, and level of training. Improvements to economy may be related to the volume of training done - i.e. large improvements in economy come after large amounts of training (piles of miles), or after a number of years of training and competition. Comparison of individual economy with that of the group can be done with an economy graph (which shows the oxygen requirements over a range of intensities for an individual and the group). An individual economy that is better than the group's is represented graphically by an economy curve that is below and to the right of the group curve. Economy curves above (or to the left of) the group curve represent individual economies that are not as good as the group.



Max VO2:	70.3
Max HR:	205
Max LACTATE:	9.0
Max RPE:	

4mM	
HR:	184.7
RPE:	15.9
WORK:	336.1

LT	
VO2:	50.0 (71.1%)
HR:	173
LACTATE:	1.7
RPE:	
WORK:	285 W

MSS 2	
VO2:	60.0 (85.3%)
HR:	192
LACTATE:	4.5
RPE:	
WORK:	350 W

USOC SPORTS SCIENCE
PHYSIOLOGY TESTING
NATIONAL CYCLING TEAM
SENIOR CAMP
DECEMBER 6-8 1991

Data Summary

Females

VO2max	Max Heart Rate	Max Lactate	%VO2max at LT
57.0	195	9.7	74.1%

%VO2max at MSS	Max Watts	Watts at MSS
88.7%	322	219

Males

VO2max	Max Heart Rate	Max Lactate	%VO2max at LT
67.4	196	11.0	70.4%

%VO2max at MSS	Max Watts	Watts at MSS
82.2%	445	300

VERTICAL JUMP

The standing vertical jump is another measure of your anaerobic power, or explosiveness. It is not as sport-specific for cyclists as the Wingate test on a bicycle ergometer, but it is simple and has been found to correlate with sprinting ability.

Vertical Jump Guideline (inches)

	Men	Women
Super	25.5 - 27.5	17..5 - 20.0
Excellent	24.0 - 25.0	16.0 - 17.0
Good	22.5 - 23.5	14.0 - 15.0
Average	21.0 - 22.0	12.5 - 13.5
Fair	19.5 - 20.5	11.0 -12.0
Poor	18.0 - 19.0	9.0 - 10.5
Very Poor	15.5 - 17.5	6.5 - 8.5

Average Vertical Jump (inches)
for U.S. National Cycling Team

Sr. Men	22.5
Sr. Women	16.2

NAME LANCE ARMSTRONG DATE 12/6/91

Your vertical jump (inches) 19.0

WINGATE ANAEROBIC POWER TEST

Power is the ability to do a lot of work in a short amount of time. On the bicycle, that translates into accelerating and going fast. Your ability to jump, catch a break or win a sprint relies on your anaerobic power and capacity.

Energy can be produced either aerobically, with oxygen, or anaerobically, without oxygen. Because it does not depend on the intake and transport of oxygen, your anaerobic system can supply energy more quickly and support higher intensity efforts than your aerobic system can.

Anaerobic energy comes from two systems- the phosphate system and the lactic acid system. Both are important in cycling. The phosphate system supplies energy for maximal intensity work, but it can only last for about 10 seconds of all-out cycling. You use this energy system when you jump or accelerate. The lactic acid system also supplies energy for intense work but it is limited by the accumulation of an infamous byproduct- lactic acid. Therefore, it can support only 1-2 minutes of very hard cycling, like bridging a gap.

The Wingate test is the most reliable and valid assessment of anaerobic power for cyclists. It involves sprinting all-out on a bicycle ergometer against a load that is a certain percentage of your body weight. The 30-second Wingate taxes both your phophate and lactic acid systems.

Your anaerobic power, determined primarily by your phosphate system, is indicated by your peak power output (in watts or watts/kg body weight). Your anaerobic capacity, determined primarily by your lactic acid system, is indicated by your mean power output (in watts or watts/kg body weight) and your total work done (in joules or joules/kg body weight). A fatigue index is also computed- the more negative the value, the greater the rate of power decay.

Subject : Lance Armstrong, Date : 7 - Dec - 1991
Weight (kg) : 80.2
Ergo. Resist. (kp) : 8.0
Ride Time (s) : 30

Time	Signals	Watts	Joules
1	16	1505.9	1505.9
2	14	1317.6	2823.6
3	12	1129.4	3953.0
4	11	1035.3	4988.3
5	11	1035.3	6023.6
6	10	941.2	6964.8
7	10	941.2	7905.9
8	9	847.1	8753.0
9	9	847.1	9600.1
10	9	847.1	10447.1
11	8	752.9	11200.1
12	8	752.9	11953.0
13	8	752.9	12706.0
14	8	752.9	13458.9
15	7	658.8	14117.8
16	7	658.8	14776.6
17	7	658.8	15435.4
18	7	658.8	16094.2
19	7	658.8	16753.1
20	7	658.8	17411.9
21	7	658.8	18070.7
22	7	658.8	18729.6
23	6	564.7	19294.3
24	7	658.8	19953.1
25	7	658.8	20611.9
26	6	564.7	21176.6
27	7	658.8	21835.5
28	6	564.7	22400.2
29	6	564.7	22964.9
30	6	564.7	23529.6

Peak Watts : 1505.9, Peak Watts/kg : 18.8
Avg. Watts : 803.1, Avg. Watts/kg : 10.0
Tot. Joules : 24094.3, Joules/kg : 300.4
Fatigue : -31.4

Average 30-Second Wingate Results for U.S. National Cycling Team

	Sr. Men	Sr. Women
Applied Load	.100 * BW	.085 * BW
Peak Power (W,W/Kg)	1410 (18.4)	803 (13.3)
Mean Power (W,W/Kg)	922 (12.0)	622 (10.4)
Fatigue Index	-26.0	-11.6

CYBEX II- MUSCLE STRENGTH

We all want to be "strong" on the bike. But how strong are your muscles? Traditional measures of strength, like the ability to lift a weight, often depend more on technique than the ability to generate force. The Cybex II is a computerized machine that measures the torque you can generate as your limb moves against a lever arm. It can provide a great deal of information about your muscle strength and muscle power.

For cyclists, the important muscles to test are the ones that flex and extend the joints that produce pedalling power- the hip, the knee and the ankle. Isokinetic strength is measured as the torque that you can produce as you move your joint at a specific speed. We test cyclists at an angular velocities that approximate the rate at which your joint angles change when pedalling at 100 rpm (300 degrees/second at the knee and 180 degrees/second at the hip).

Muscle strength is indicated by the peak torque (in footpounds or ft-lb/kg body weight) that you are able to produce. For each joint tested, you produce a peak torque in one direction, extension, as well as the other direction, flexion. Several muscles may be involved for each movement. At the hip, extension tests the gluteus maximus mainly while flexion tests the psoas. At the knee, extension tests the quadriceps while flexion tests the hamstrings. At the ankle, extension tests the gastrocnemius predominantly while flexion tests the tibialis anterior.

Absolute muscle strength is important- it has been related to endurance- but muscle balance is equally important. Balance of muscle strength, both front-to-back and side-to-side is crucial for preventing injury and producing power efficiently. Your hamstring/quadricep strength ratio should be about 60%. The muscles on your right side should match the muscles on your left side in strength. More than a 10% difference is undesirable. Muscle strength and its balance is especially important to measure and monitor if you are weight training or recovering from an injury and have lost some strength.

CYBEX II TEST RESULTS

NAME LANCE ARMSTRONG DATE 12/6/91

KNEE (speed = 300 deg/sec)

	Right	Left	Ave ft/k
Quadricep Peak Torque (ft-lb, ft-lb/Kg)	51.2	53.5	.65
Hamstring Peak Torque (ft-lb, ft-lb/Kg)	33.3	40.8	.4
Ratio Hamstring/Quadricep	65%	76%	

Quadricep Ratio Right/Left .96

Hamstring Ratio Right/Left .82

HIP (speed = 180 deg/sec)

	Right	Left
Extensor Peak Torque (ft-lb, ft-lb/Kg)		
Flexor Peak Torque (ft-lb, ft-lb/Kg)		

Extensor Ratio Right/Left ________

Flexor Ratio Right/Left ________

Cybex II Muscle Strength
Averages for U.S. National Cycling Team

Sr. Men

KNEE (speed = 300 deg/sec)

	Ft-lb	Ft-lb/Kg
Quadricep Peak Torque	71.4	.93
Hamstring Peak Torque	49.4	.65
Ratio Hamstring/Quadricep	69%	

HIP (speed = 180 deg/sec)

	Ft-lb	Ft-lb/Kg
Extensor Peak Torque (ft-lb, ft-lb/Kg)	145.3	1.88
Flexor Peak Torque (ft-lb, ft-lb/Kg)	89.7	1.16

Sr. Women

KNEE (speed = 300 deg/sec)

	Ft-lb	Ft-lb/Kg
Quadricep Peak Torque	51.3	.86
Hamstring Peak Torque	32.2	.54
Ratio Hamstring/Quadricep	63%	

HIP (speed = 180 deg/sec)

	Ft-lb	Ft-lb/Kg
Extensor Peak Torque (ft-lb, ft-lb/Kg)	96.5	1.60
Flexor Peak Torque (ft-lb, ft-lb/Kg)	48.8	.81

PULMONARY FUNCTION

Pulmonary function involves two major processes: 1) getting air into and out of the lungs and 2) exchanging oxygen and carbon dioxide gases between the lungs and the blood. Assessment of the first function includes measurement of lung volumes and capacities. Many of these are dependent on your body size, age, gender and race. There is some controversy about how training may affect these measures, so that having high values is not so important as just being "normal". In other words, training may not improve values, and having high values does not necessarily relate to improved performance. Rather, abnormally low values may limit performance (asthma or restricted breathing, for example).

The pulmonary function test, which simply involves breathing into a machine called a spirometer, is done both before and after 10 minutes of hard cycling on an ergometer. The pre-exercise test evaluates lung subvolumes, maximal voluntary ventilation and maximal expiratory flow-volume characteristics (forced vital capacity maneuver). The post exercise test, which only includes the forced vital capacity maneuver, is done 1, 5, 10, 15 and 20 minutes after exercise to check for exercise induced bronchospasm.

What do the most important values mean?

FVC: Forced Vital Capacity is the greatest amount of air that you can expel following a maximal inspiration.

MVV: Maximal Voluntary Ventilation is the total volume of air you can exhale over about 15 seconds (with repeated maximal breaths).

FEV1: Forced Expiratory Volume in 1 Second is how much air you can blow out in one second.

FEF 25-75%: Forced Expiratory Flow between 25% and 75% of forced vital capacity is the amount of air blown out when your lungs are between 3/4 and 1/4 full.

PEFR: Peak Expiratory Flow Rate is the fastest rate you can blow the air out.

Exercise-Induced Bronchospasm (EIB)

Exercise-induced bronchospasm is characterized by high resistance to airflow into and out of the lungs during or after exercise. Most asthmatics experience this constriction of airway passages brought on by exercise, but in some people EIB is the only manifestation of their asthmatic tendency. Most pulmonary specialists consider a 15% decrease in FEV1 or PEFR diagnostic of EIB. EIB can successfully be treated in a number of ways. If you are diagnosed with EIB, you will be referred to a physician.

EIB Screening

NAME: Lance Armstrong DATE: 12/6/94

Predicted FEV_1 451

PRE Exercise FEV_1 5.42 (Baseline)

PD_{20} (baseline × 80%) 4.336

POST EXERCISE FEV_1

1 minute 5.63

5 minute 4.95

10 minute 5.08

15 minute 4.88 *

20 minute /

*If any post exercise FEV_1 value is lower than the PD_{20} value, this may indicate EIB

May be slight obstruction

SKINFOLD NORMS

SPORT: CYCLING SEX: MALES

The skinfold measures that were taken on you in our Laboratory are listed below. Beside each is the AVERAGE value for all cyclists measured in our laboratory as of May 1986.

NAME: [illegible]

	Your Value	Average Value
AGE	[illegible]	
WEIGHT (kg)	77.[illegible]	
HEIGHT (cm)	[illegible]	
(SKINFOLDS)		
CHEST	[illegible]	
AXILLA	5	
TRICEP	4.5	
SUBSCAPULA	7	
NAVEL	6	
HIP	4	
THIGH	6	
SUM OF 7	32.[illegible]	

DATE: ______

TESTED BY: 1-26-[illegible]

UNITED STATES OLYMPIC COMMITTEE
ATHLETE PERFORMANCE DIVISION
PHYSICAL CONDITIONING AND TRAINING PROGRAM
COLORADO SPRINGS, COLORADO

NAME:	Lance Armstrong	DATE:	1/26/1995
AGE:	23.0 years	SPORT:	US Pro Cycling
GENDER:	Male	RACE:	White
WEIGHT:	77.70 kg 170.94 lbs	TESTED BY:	SH
HEIGHT:	178.50 cm 71.12 in		

*** BODY COMPOSITION : 7 SITE SKINFOLD TEST ***

SITE	YOUR AVERAGE
CHEST	5.5
AXILLA	5.0
TRICEPS	4.5
SUBSCAPULAR	7.0
ABDOMINAL	6.0
SUPRAILIUM	4.0
THIGH	6.0
TOTAL	38.0

RESULTS

BODY DENSITY: 1.0896
% BODY FAT: 4.28
SUM OF SKINFOLDS: 38.0 mm

	Metric	English
WEIGHT OF BODY FAT:	3.33 kg	7.32 lb
FAT FREE WEIGHT:	74.37 kg	163.62 lb

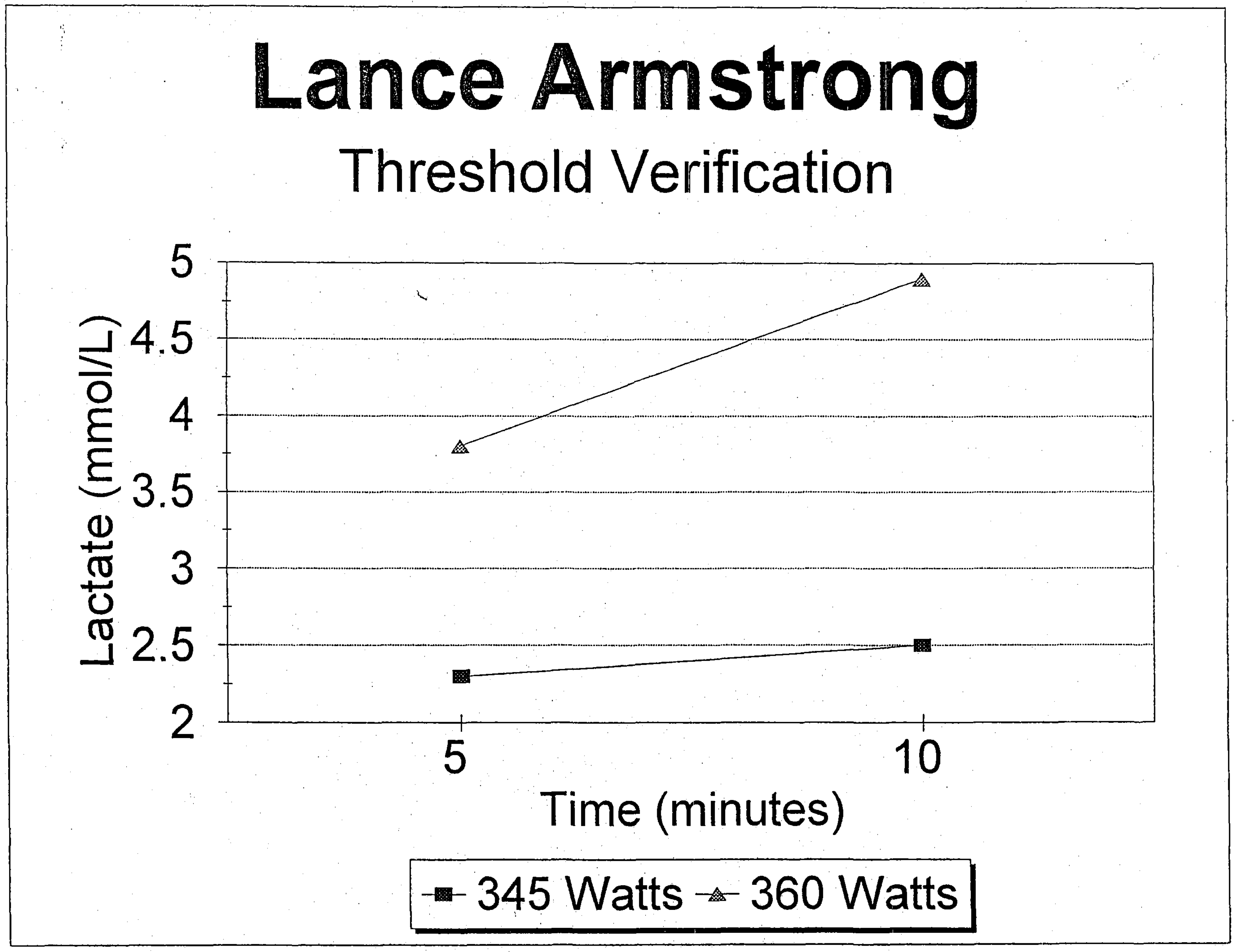
The % fat values estimated via skinfolds can vary by +/- 3%. Our calculation for you is 4.28%, but the actual value may range from 1.28% to 7.28%.

Reference:

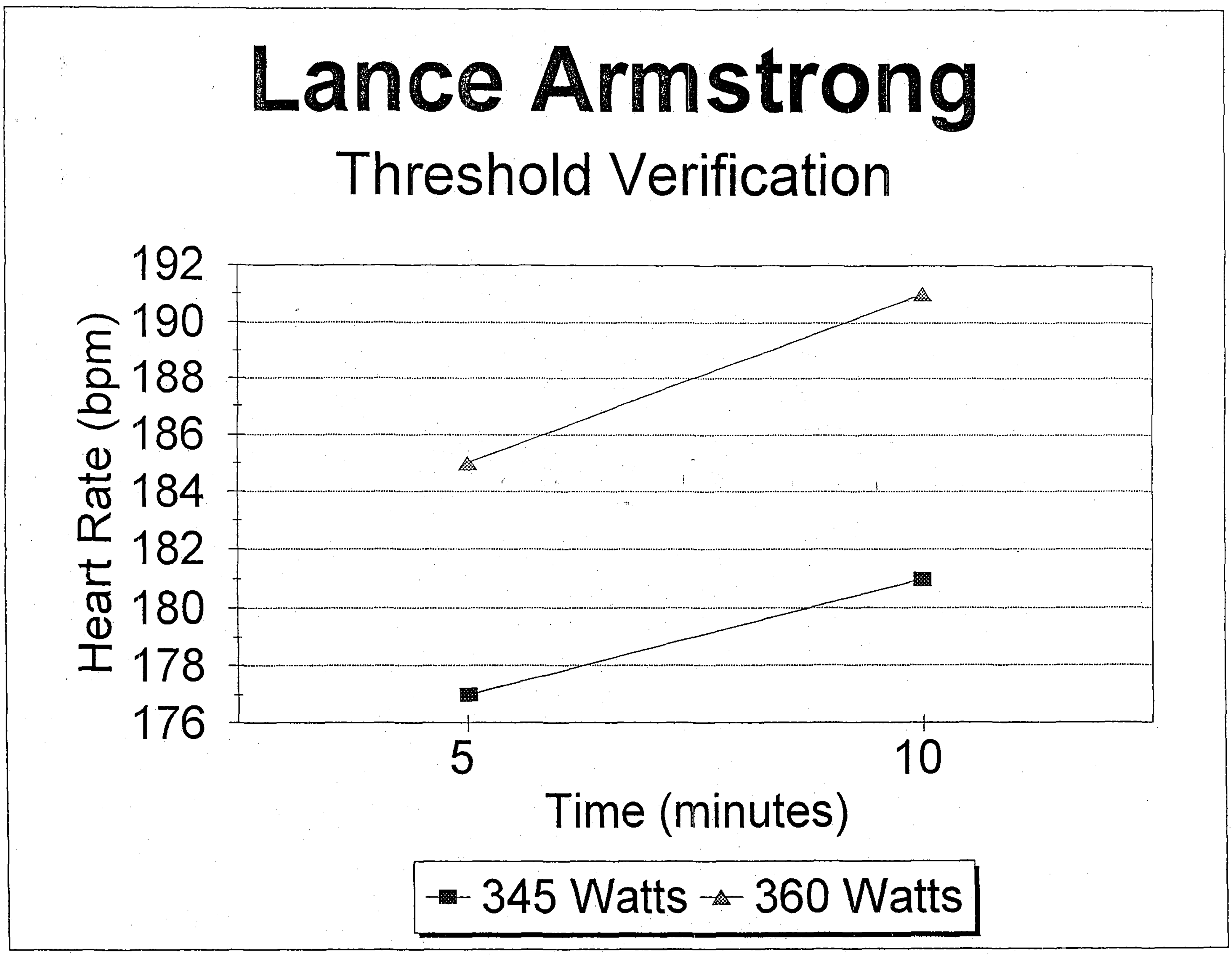
A.S. Jackson et al., 'Generalized Equations for Prediciting Body Density of Women', Medicine and Science in Sports, 1980.

A.S. Jackson and M. L. Pollack, 'Generalized Equation for Predicting Body Density of Men', British Journal of Nutrition, 40(1978):497-504.

J.E. Schutte et al., 'Density of Lean Body Mass is Greater in Blacks than in Whites', Journal of Applied Physiology, 56(1984):1647-1649



Lance Armstrong
Threshold Verification
Lactate (mmol/L)
5
4.5
4
3.5
3
2.5
2
5
10
Time (minutes)
345 Watts
360 Watts



26 January 1995

NAME LANCE ARMSTRONG Date 1-26-95

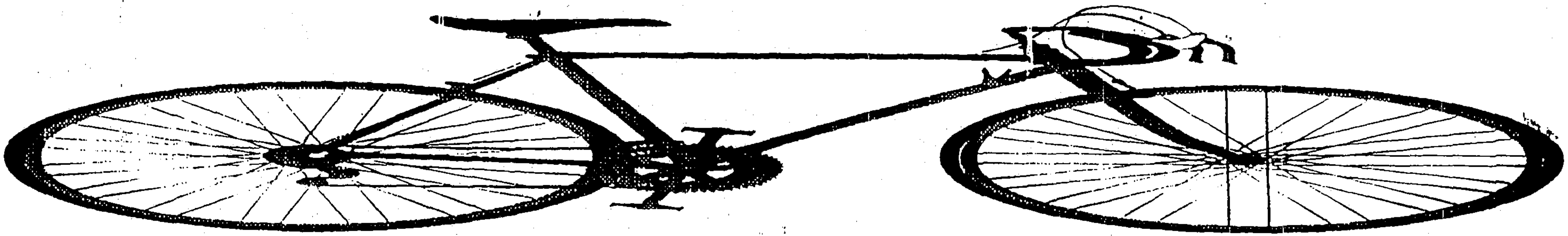
SENSORMEDICS File ______

POLAR Watch 3 File 3c

XGRAF File ______

Cycling Data Form

Athlete Performance Division



WT: ______

HT: ______

AGE: ______

DATE: ______

GENDER: ______

TIME	WATTS	HEART RATE	RPE	LA	VO2	SaO_2
0-4	345 W 5'			2.3		
4-7	10'	191	15	2.5		[illegible]
7-10	5'	[illegible]		1.2		
10-13	360 W 5'	18[illegible]	18	3.[illegible]		
13-16	10'	191	19	4.9	9[illegible]	92
16-19	15'	—				
19-22	375 W 5'	—				
22-25	10'	—				
MAX	15'	—				

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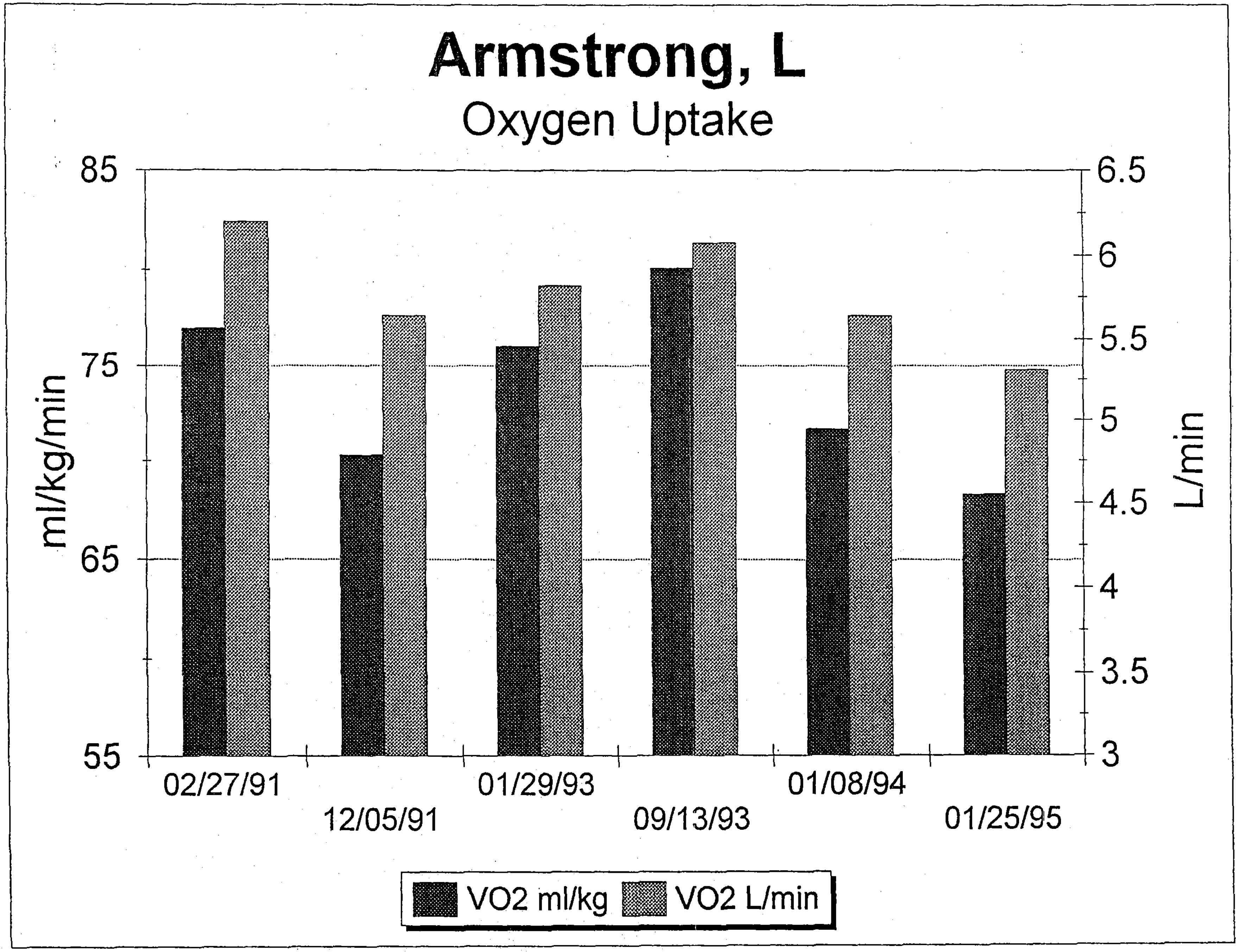
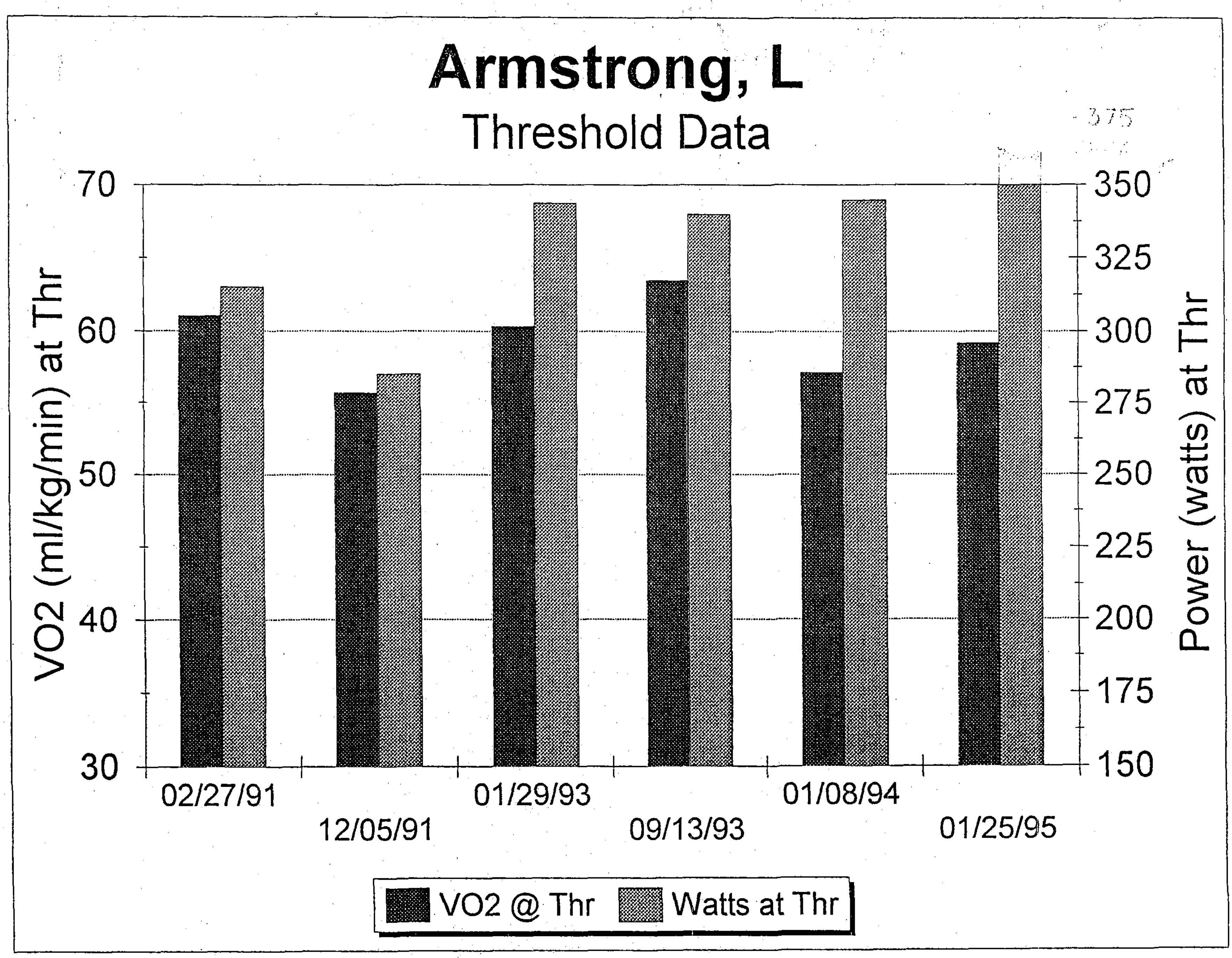

Armstrong, L
Oxygen Uptake
85
75
65
55
6.5
6
5.5
5
4.5
4
3.5
3
ml/kg/min
L/min
02/27/91
12/05/91
01/29/93
09/13/93
01/08/94
01/25/95
VO2 ml/kg
VO2 L/min


Armstrong, L
Threshold Data
VO2 (ml/kg/min) at Thr
Power (watts) at Thr
70
60
50
40
30
350
325
300
275
250
225
200
175
150
375
02/27/91
12/05/91
01/29/93
09/13/93
01/08/94
01/25/95
VO2 @ Thr
Watts at Thr

UNITED STATES OLYMPIC COMMITTEE

MEMORANDUM

DATE: October 26, 1993

TO: Lance Armstrong
Chris Carmichael
Lisa Voight, Executive Director USCF
Tad Springer, Technical Director, Atlanta Project

FROM: Jeff Broker, Jay T. Kearney

RE: Atlanta Project Test Program for Lance Armstrong

Please find attached a report summarizing recent physiological and biomechanical testing performed for 1993 Cycling World Champion Lance Armstrong. The testing was a huge success, and resulted in the following key findings:

- Lance's maximum oxygen uptake is 80 ml/kg/min, within 10% of the highest in the world.
- Lance's anaerobic threshold at 60.1 ml/kg/min, 75% of VO2 max, can be increased 5 to 10 % through appropriate training.
- Lance's pedalling mechanics are symmetric and sound, and can be improved to enhance smoothness.
- Aerodynamic modifications to Lance's geometry on his bicycle and his helmet can dramatically improve his time-trial performance. On the track, adjustments to Lance's position and helmet resulted in a 10% reduction in power consumption at a fixed speed of 30 mph, and a 0.9 mph increase in speed for the same level of effort! Coupled with training induced physiological adaptations, Lance can realistically cut at least nearly 4 minutes off his 40K time-trial time.

Additional tests on Lance are scheduled for December of this year, or January of next year. We hope to continue supporting Lance through Atlanta in 1996. His presence in our laboratories was inspirational. Lance is truly a gentleman as well as a superb athlete, and it was a pleasure to work with him.

continued ....

This test effort reflects the nature of services we plan on providing to target Atlanta Project athletes as part of our Sports Science and Technology support effort. In addition, future services to Atlanta Project athletes will include Sport Psychology – directed by Sean McCann. The success of the test program for Lance Armstrong was largely due to the cooperative efforts of Lance, Chris Carmichael, Ed Burke, and the Sports Science and Technology staff. Similar efforts will be necessary to provide the same quality level of service to the remaining target Atlanta Project athletes.

Thanks to everyone who assisted with the test program.

JPB/jb
cc: Attachment*

SST Atlanta Project Team	USCF	SS&T Committee	
Jeff Broker*	Dick Wiles*	Andy Kostanecki	Walt Wilson
Jay T. Kearney*	Ed Burke*	Bob Gregor*	Shane Murphy
Sean McCann*	Mark Gorski*		Audrius Barzdukas
Tom Westenburg			
Karla Coughlin			
Allana Albrecht*			
Randy Wilbur*			
Kathy Zawadski*			

Lance Armstrong
September 13-15, 1993

Introduction

Lance Armstrong, 1993 World champion cyclist, came to the Olympic Training Center in early September for 3 days of physiological and biomechanical testing. The objectives of the test program were (1) to evaluate Lance's time-trial capability at peak condition (just coming off of the World Championships), (2) to identify areas for improvement in Lance's time-trial performance that can be addressed through modifications in rider/bicycle positioning and training, and (3) to establish baseline measures of physiological and biomechanical performance for comparison with data collected in future test sessions. Testing was conducted in the Biomechanics and Physical Conditioning Laboratories at the Olympic Training Center, and at the 7-Eleven Velodrome in Colorado Springs, CO.

Testing Procedures

Day 1. The first day of testing concentrated on physiological measures of cycling performance. Physiological testing during day 1 included both submaximal and maximal aerobic power tests. The submaximal test consisted of an eight stage protocol with the first stage of 200 watts lasting 4 minutes and subsequent stages of 250, 275, 300, 325, 350, 375 and 400 watts lasting 3 minutes. Expired air was collected continuously throughout the test for measurement of oxygen uptake. During the last minute of each stage, heart rate was recorded using a Polar Vantage XL heart rate monitor and the subject was asked to give a rating of perceived exertion (on a scale of 6 to 20, with 20 representing a supramaximal effort). A blood sample was collected at the end of each workload by a finger prick and was immediately analyzed for lactate concentration. An anaerobic threshold was determined from the data collected.

After a rest period of approximately 10 minutes, the subject began a test for maximal aerobic capacity. The workload began at 400 watts and was increased by 25 watts every minute until voluntary fatigue. Expired air was collected continuously throughout the test for measurement of oxygen uptake. Maximal heart rate and oxygen uptake were recorded at the completion of the test and a blood lactate sample was collected 2 minutes post-test.

The afternoon consisted of evaluating the subject's cycling economy and optimal pedaling frequency. A workload just below the subject's anaerobic threshold (325 watts), was chosen so that his threshold response across various pedaling rates could be evaluated. The pedaling frequencies evaluated were 70, 75, 80, 85, 90 and 100 rpms. Each trial was 5 minutes in duration with a 5 minute recovery period between trials. During each stage heart rate was recorded using a Polar Vantage XL heart rate monitor and expired air was collected for measurement of oxygen uptake. Following each trial, blood lactate was measured after 2 minutes of recovery.

Day 2. On the second day of testing, additional physiological and biomechanical tests were conducted. In the morning, Lance underwent a simulated sea-level VO_2 max test. Lance breathed an oxygen mixture of 26.08%, simulating sea-level cycling, using the same protocol as the maximal oxygen uptake test performed the previous day. The objective of the sea-level test was to compare values obtained during a prior test conducted at the University of Texas in Austin in January of 1993.

In the afternoon on the second day, a variety of biomechanical tests were conducted. First, Lance's pedal force and motion patterns at threshold levels were recorded using the Sports Science and Technology's instrumented force pedals. Lance rode a laboratory bicycle, configured to replicate his own time-trail bicycle's geometry, mounted to a Velodyne road simulator. The simulator regulated power output independent of cadence. Lance rode at 70, 75, 80, 85, 90 and 100 rpms for 2-3 minutes at 325 watts. Variables quantified during the force pedal testing included power and work symmetry, power and recovery phase force patterns and ankling technique.

Leg segment positions were recorded using high-speed cameras during the pedalling mechanics testing. Subsequent analysis of Lance's pedal force and leg motion patterns will characterize joint torque and power profiles across cadences. Since this was the first series of tests of this nature for Lance, the data collected will document baseline mechanics for comparison later in the test program, as well as later in his career.

After the pedalling mechanics testing, Lance's aerodynamic positioning on his bicycle was evaluated. Lance was videotaped from the side in his normal time-trialing position while pedaling easily on his bicycle mounted to a turbotrainer. Using Tour du Pont race videos and the laboratory video, representative images of Lance in his racing position were then generated. The race and laboratory videos documented the flatness of Lance's back, the position of his head, and the position of his arms. From the video data, recommendations concerning seat position, handlebar clip-on configuration and placement, head position, and helmet geometry were generated and explored. These recommendations were then tested the following day at the Velodrome.

Day 3. Lance was evaluated on the 7-Eleven Velodrome on the third day to compare actual riding characteristics to the laboratory findings. Variables measured during the track testing included bicycle speed, bicycle power, and heart rate. After a 15 minute warm-up, Lance rode continuous trials at 24, 26, 28, 30 and 32 mph. He first rode his standard time-trial bike (Eddy Merckx frame, 72 degree seat tube adapted with Profile Aero II XL clip-on bars) equipped with a Polar Vantage XL recorder, Avocet cyclocomputer and a special Power Pacer rear hub. Lance alternately reported his heart rate and power output each time he completed a lap around the track. A total of 4 to 6 laps at each test condition were performed. Due to exhaustion, Lance was unable to perform the 32 mph condition.

After completing the standard racing position trials, Lance rested and his bicycle was modified. A curved seat post was installed on Lance's bicycle which moved his seat forward 6 cm. Lance's seat was raised 6 mm to account for the forward position of the seat and associated pelvic rotation. Lance's Profile clip-on handlebars were changed to AirStryke bars, and his handlebar stem was lowered 2 cm. The seat and handlebar positional changes effectively rotated Lance's hips forward, flattened his back, and moved his elbows closer together - producing a more streamlined, aerodynamics form. Lance's specialized helmet was replaced with an aerodynamic track helmet (manufacturer to be unnamed). After a 10-minute warmup in the modified position, the incremental speed tests on the track were repeated using the same protocol described for the standard riding position (i.e. , 4 to 6 laps at 24, 26, 28, 30, and 32 mph). Lance was able to complete the 32 mph test condition in his more aerodynamic position.

Results

Physiological Tests

Maximal oxygen consumption represents the maximum amount of oxygen that the body's tissue can consume to provide energy. During exercise of extended duration (such as road cycling), the body relies heavily on aerobic pathways – but also depends on the anaerobic pathway when energy needs become excessive, for instance in sprinting or bridging gaps. Therefore, the more highly developed the oxygen consuming process (higher VO_2 max), the less the body must rely on the anaerobic pathway.

Lance's VO_2 max was 80.09 ml/kg/min (consumption of oxygen in milliliters per kilogram per minute) while reaching a peak workload of 500 watts. At VO_2 max, Lance's heart rate was 200 bpm and lactate was measured at 6.5 mmol. His lactate measurements were lower throughout the entire test than values usually seen for such an exhaustive test. This is in agreement with values obtained for this subject during previous testing. Average maximal lactate values obtained from national team cyclists were 12.21 $\pm$ 2.09 mmol. It is not known if Lance produces less lactate than the average cyclist or if he is able to clear the lactate at a faster rate so that it does not accumulate in his muscle or blood.

An important predictor of performance in steady state events, such as time-trialing, is the percent of VO_2 max that can be maintained for the duration of the race. The lactate threshold can be determined by measuring blood lactate accumulation during an incremental test and relating it to a percentage of VO_2 max. Lactate threshold can be used as an indicator of the highest exercise workload that an individual can maintain for an extended period of time. Lance's lactate threshold was measured at 60.1 ml/kg/min, which correlates to 75% of his VO_2 max (see Figure 1). Power production at lactate threshold was 340 watts. For Lance to be able to successfully compete in time-trial events, he will need to consistently produce over 400 watts. This will require raising his lactate threshold through proper training techniques. Average lactate threshold values for a group of national senior cyclists was 81.5% of VO_2max.

With the simulated sea-level test, there was no change in VO_2 max (80.3 ml/kg/min). It is typical to see values 5 to 10% higher at sea level than at altitude. This is due to a small decrease in the percent saturation of hemoglobin (the oxygen carrying protein in blood) at altitude. For example, hemoglobin may be only 90% saturated at 1900 m, . The test shows an exceptionally positive adaptation of Lance to altitude. There appears to be no loss of arterial saturation of hemoglobin, even at 1860 meters above sea level. When compared to riders that may be susceptible to arterial desaturation at altitude, Lance would have a definite competitive advantage. Lance can be expected to race extremely well at altitudes above 1500 meters.

A racer's economy represents the relative oxygen cost at a given submaximal workload. At a given pace, a less economical cyclist can use more energy than a more economical rider. Therefore, the cyclist who can achieve a power output using a lower amount of oxygen will have a competitive advantage. Comparing Lance's values to the hundreds of tests completed at the Training Center showed that he was slightly more (1%) economical than the average elite cyclist.

There is some evidence that while time-trialing, cyclists may be more economical at cadences of 70 to 85 rpms. They are pushing larger gears and pedaling at lower rpm's. To evaluate if Lance is more economical at a lower pedal cadence, a comparison of the oxygen cost at the various pedaling rates was done.

Table 1. Economy Test. The data collected during the 6 trials is summarized below.

Trial	Cadence	Ve (L/min)	VO2 (ml/kg/min)	RR	Avg HR	Max HR	HLa (mmol)
1	90	95.0	55.6	30	167	170	2.35
2	70	91.2	55.8	31	163	166	2.75
3	100	106.6	58.1	35	171	175	1.61
4	75	99.7	56.3	33	166	167	1.48
5	85	101.5	56.1	35	166	170	1.19
6	80	102.5	56.2	36	163	167	1.05

As can be seen from Table 1, there was little difference between trials. At 100 rpms slight increases were noted for Ve and HR. At 90 rpm, his current favored cadence, values for VO_2, Ve and RR (respiratory rate) were slightly lower. Blood lactate levels were higher during the first trial, but this may be attributed to the fact that it was the first trial and the subject was not completely warmed up. The same trend was noticed during his submaximal test.

Biomechanics

Lance's pedal angle profile and force patterns are illustrated in the Figures 2 and 3, respectively (attached). At 325 watts (90 rpm), Lance was highly symmetric in both his pedal motion and work output. He exhibited slightly more ankling (dropping the heel in the down stroke of the pedal cycle) on his right side (Figures 2 and 3). This observation, although meaningless from a performance standpoint, could be associated with a small leg length discrepancy, a slight pelvic tilt on the saddle, a small flexibility or strength difference between legs, or a combination of any of these factors. Furthermore, Lance performed 51.5 percent of the total pedalling work on his right side, and 48.5 percent on his left. This difference is negligible (much less than most elite cyclists), and is primarily caused by him being slightly heavier on the left pedal during recovery (as the left pedal is rising). This is illustrated in Figure 3.

The only noticeable weakness identified in Lance's pedalling technique is at the top and bottom of the pedal cycle. During these phases of the pedal cycle, Lance delivers very little energy to the pedals (illustrated by the direction of the force vectors on the pedals in Figure 3). If Lance could enhance his push through the top of the pedal cycle and his pull-back through the bottom, energy delivery to the pedals would be distributed more evenly throughout the pedal cycle - creating a smoother pedalling motion. Enhanced power delivery to the pedals through the top and bottom of the pedal cycle would also serve to reduce the demand on Lance's legs during the power phase (first half of the pedal cycle) at constant power output (or speed). One-legged pedalling on a stationary trainer or one-legged dominance during road riding are effective methods to enhance this pedalling smoothness.

Lance's aerodynamic position during time-trialing (e.g., Tour du Pont) presented considerable frontal area and caused marked air flow disruption to the air stream. Of particular concern was the angle of Lance's trunk (angled slightly upward into the wind) and the height and position of Lance's helmet (tall, with the tail often projecting up into the airstream). Lance's arms were also spaced apart, permitting the wind to stall against his upper torso. Lance's normal time-trialing position is shown on the left side of Figure 4.

To obtain a flatter trunk and back angle, it was suggested that Lance move forward on his saddle (in the laboratory), gripping the clip-ons further forward of the handlebar stem. This position, replicated to some degree in the laboratory (without moving the seat), lowered Lance's head and back nearly 2 inches, and created a much flatter black (right side of Figure 4). The forward position also rotated Lance's head slightly (chin upward), causing the tail of his helmet to be placed lower (toward his back) and out of the airstream. A tighter fitting helmet with an extension into Lance's back would further reduce aerodynamic drag about Lance's head.

Integrated Track Testing

When testing at the Velodrome, power outputs and heart rates were recorded at speeds ranging from 24 to 32 mph. Data were collected first while Lance was riding his conventionally configured time-trial bicycle. After he rested and aerodynamic modifications were made to his bicycle and helmet, Lance repeated the test. Power outputs were comparable at 24 and 26 mph, however, the power required to maintain 30 mph in the aerodynamic position was approximately 47 watts lower than when riding in his existing time-trial position (Figure 5). Further, Lance was able to ride the modified bicycle 0.9 mph faster at comparable bicycle power outputs (efforts). Finally, Lance was able to complete the 32 mph trial only on the modified bike. The data confirm the significant affect that aerodynamic positioning and equipment can have on Lance's time-trial performance.

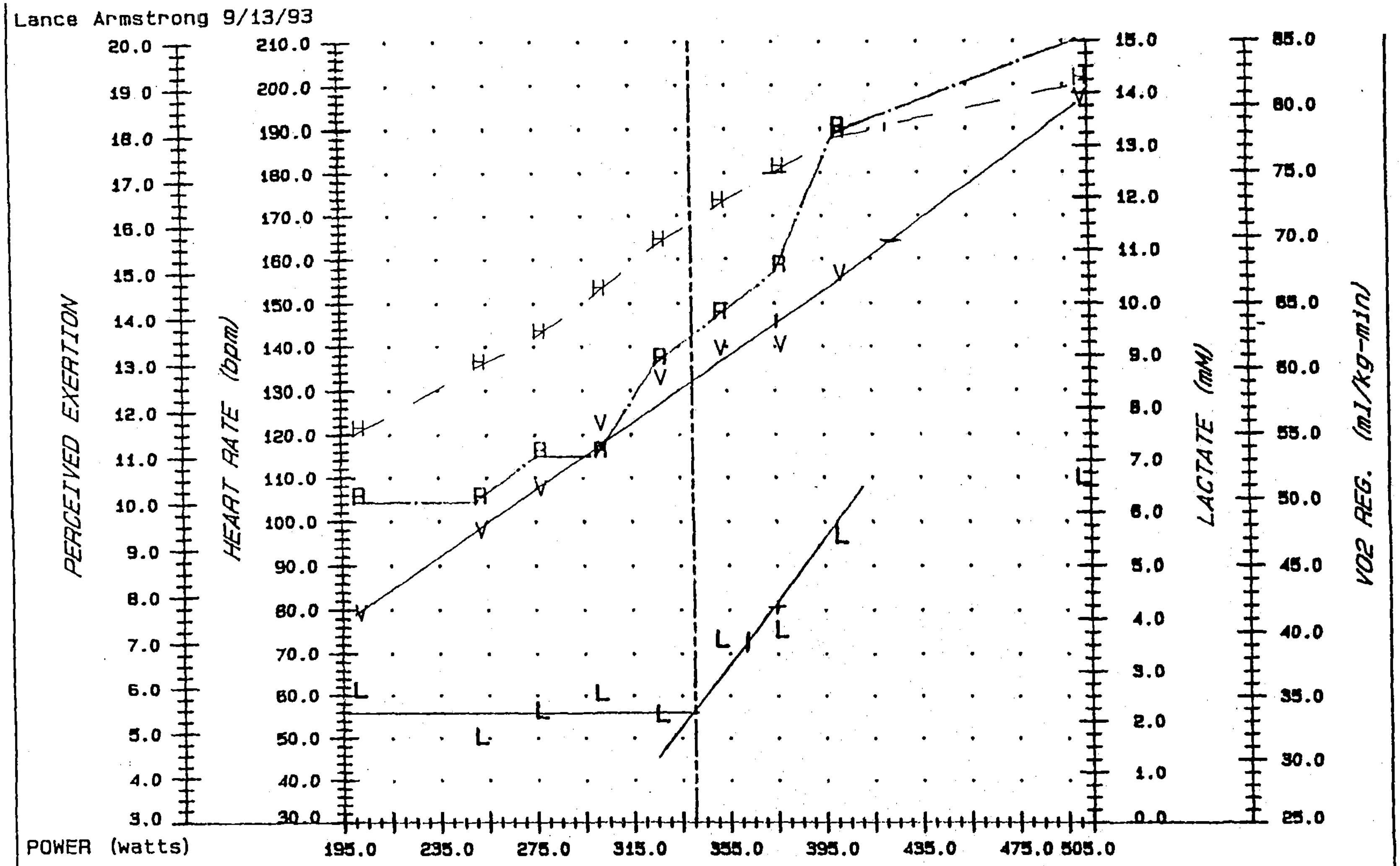
Lance's current anaerobic threshold of 75% correlates to a power output of 340 watts and a speed of 27.48 mph. Using the new aerodynamic position and riding at his current threshold he could maintain a speed of 27.92 mph without developing significant amounts of lactate. If, through training, Lance could increase his anaerobic threshold to 80% of his max, he could maintain a speed of 28.27 mph (Figure 6). With application of the aerodynamic modifications the speed could be increased further to 28.92 mph. An additional increase in his threshold to 85% of his VO_2 max theoretically translates to a speed of 28.91 mph on his current bike and 29.61 mph with the aerodynamic position. These data help the cyclist to realize that at speeds around 30 mph the aerodynamic modifications are equal to a 5% shift in anaerobic threshold.

An alternative way of presenting these threshold power and aerodynamic modification data is to calculate times for a 40K time-trial. At his current lactate threshold of 75% of VO_2 max, it would take Lance approximately 53:54.5 to complete the time-trial on his traditional bike. Using the aerodynamic modifications riding at his current threshold he could reduce his time by 51 seconds (see Figure 7). With an improvement in his lactate threshold to 80% of his VO_2 max, he should be able to complete the 40K in 52:25.5, and by combining the increase in threshold with the aerodynamic modifications, he could save an additional minute and 12 seconds.

Important Note: Due to slight overestimations in power output for a given speed on the track (associated with small instrumentation errors), the speeds at which anaerobic threshold actually occur (for each aerodynamic position) are probably higher for Lance. Consequently, increases in anaerobic threshold occurring as a result of training will probably result in higher speeds than indicated in Figure 6, and associated lower 40K times as indicated in Figure 7. Finally, the speeds and times indicated in Figures 6 and 7 reflect estimated anaerobic threshold effort levels. To the extent Lance can sustain power outputs in excess of his anaerobic threshold, Lance can go even faster and record lower 40K time-trial durations.

Conclusions

All of the data collected were reported to Lance Armstrong and his coaches. Jay T. Kearney, Ph.D and Jeff Broker, Ph.D provided an in-depth analysis of the tests and implications for training. The data collected will be used to make training adaptations and equipment modifications to help improve the performance of the World Champion.



Max VO2:	80.1	HR at 4mM:	181.5	POWER Threshold:	340.3
Max HR:	200.0	RPE at 4mM:	15.6	VO2 at Threshold:	60.1
Max LACTATE:	6.5	POWER at 4mM:	379.8	HEART RATE at Threshold:	168.5
Max RPE:	20.0	POWER, 75max VO2:	340.3	LACTATE at Threshold:	2.9
Max VO2 REG:	80.1	POWER, max VO2:	500.0	RPE at Threshold:	13.6
				VO2 REGRESSION at Threshold:	59.0

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Figure 1: Submaximal and Maximal Aerobic Power Test.

Heart rate (H), rating of perceived exertion (R) and blood lactate levels (L) are plotted against power output. Oxygen consumption (V) is displayed as a regression line. Lance's lactate threshold is indicated by the dashed vertical line. His blood lactate at threshold was 2.9 mmol, and corresponds to 75% of his VO_2max. Power production at threshold was 340 watts.

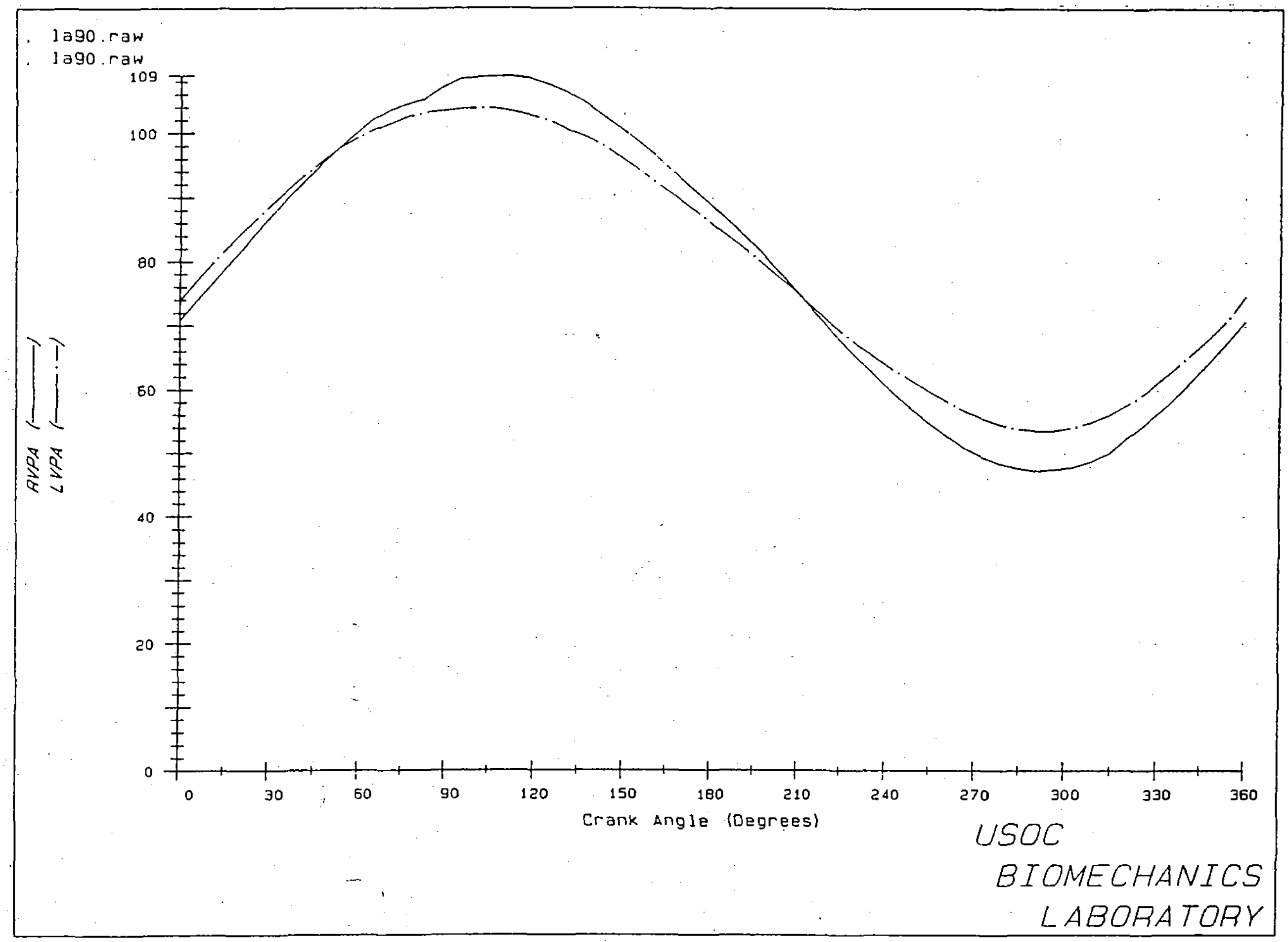


Figure 2: Pedal Angle Profiles

Pedal angle profiles for the 325 watts, 90 rpm condition are plotted vs crank angle. Crank angles of zero and 360 degrees occur when the pedals are at the top of the pedal cycle. Maximum pedal angles occur approximately 95 to 105 degrees into the pedal cycle, during the power phase. Lance exhibits slightly larger pedal angle excursion on the right side (solid line) then the left side (dash-dot line). These differences, however, are not significant.

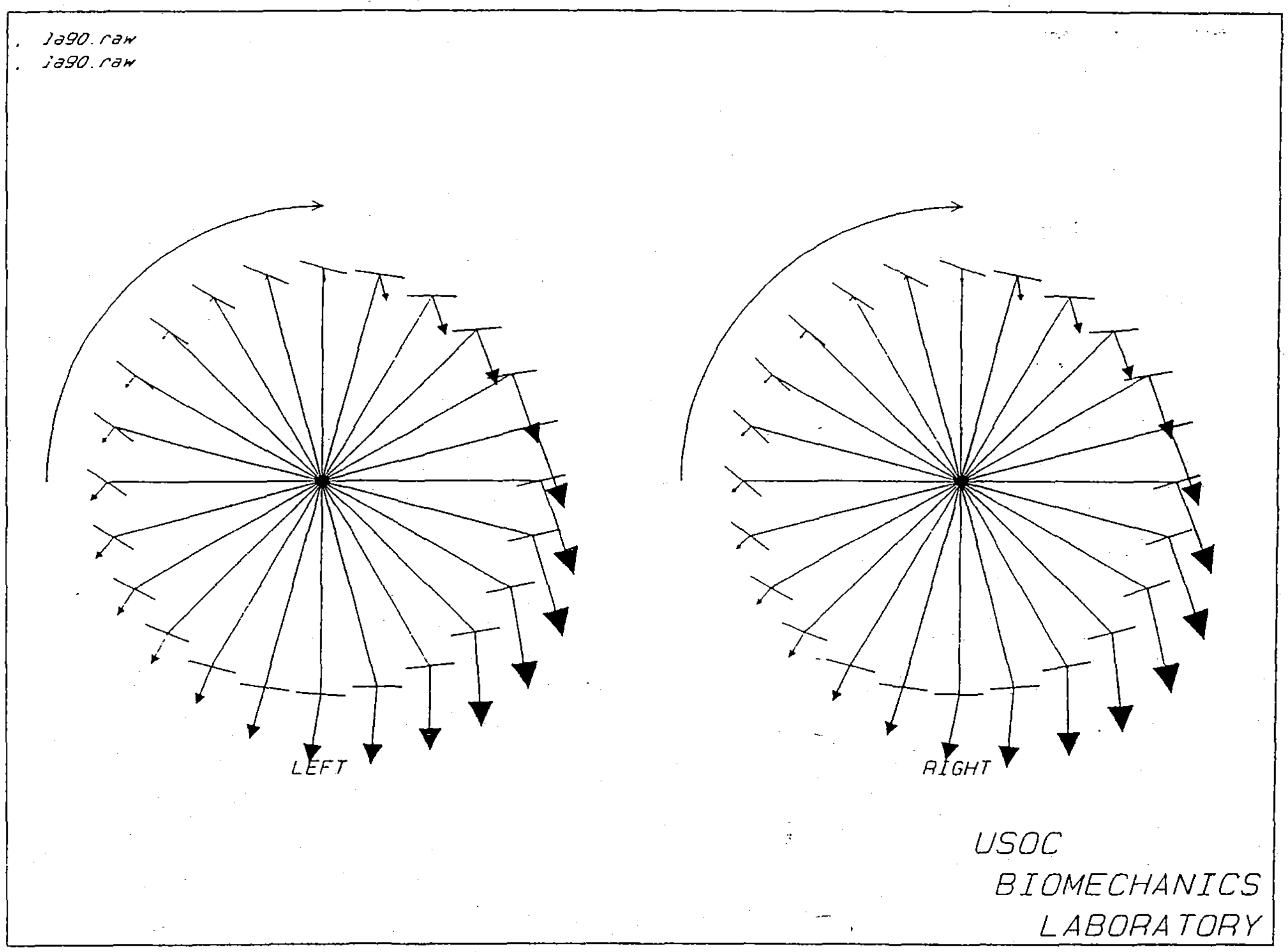


Figure 3: Clock Diagrams

Arrows indicate direction and magnitude of forces applied to each pedal. Pedal loading at the top and bottom of the pedal cycle should be directed somewhat in the direction of pedal motion to be productive. Counterproductive pedal loading during recovery (upstroke) is normal, but should be small.

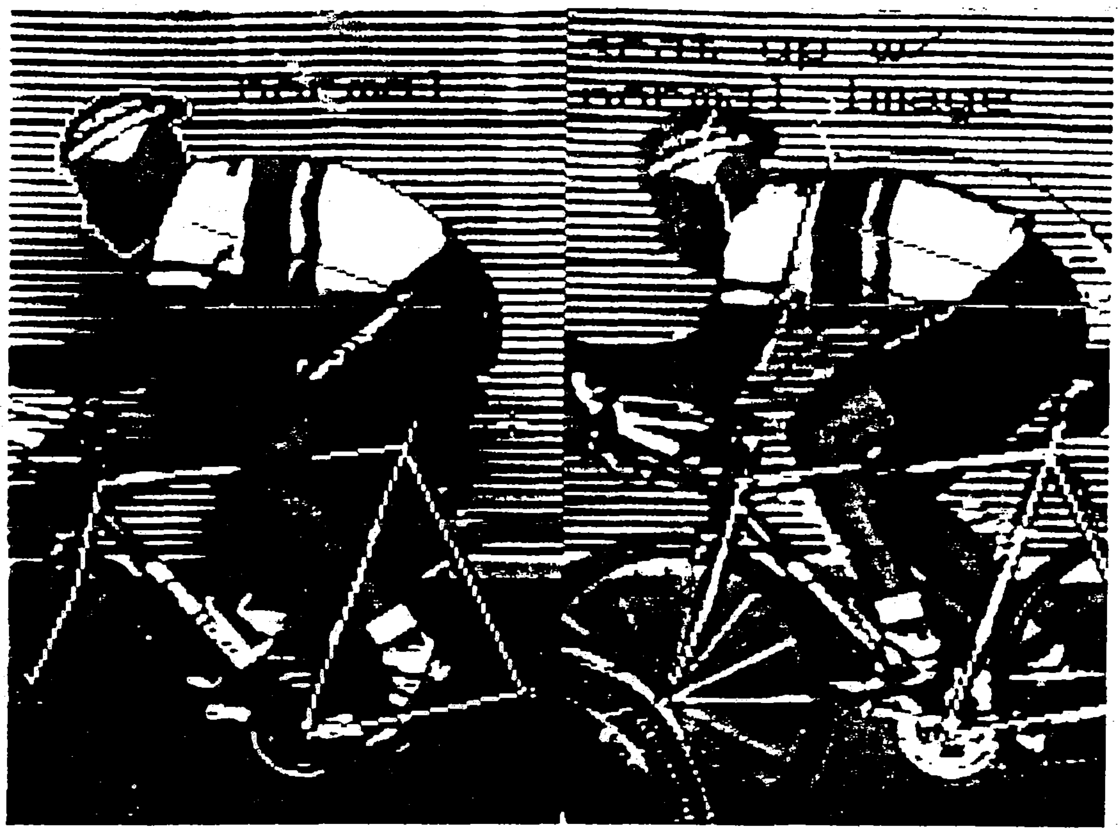
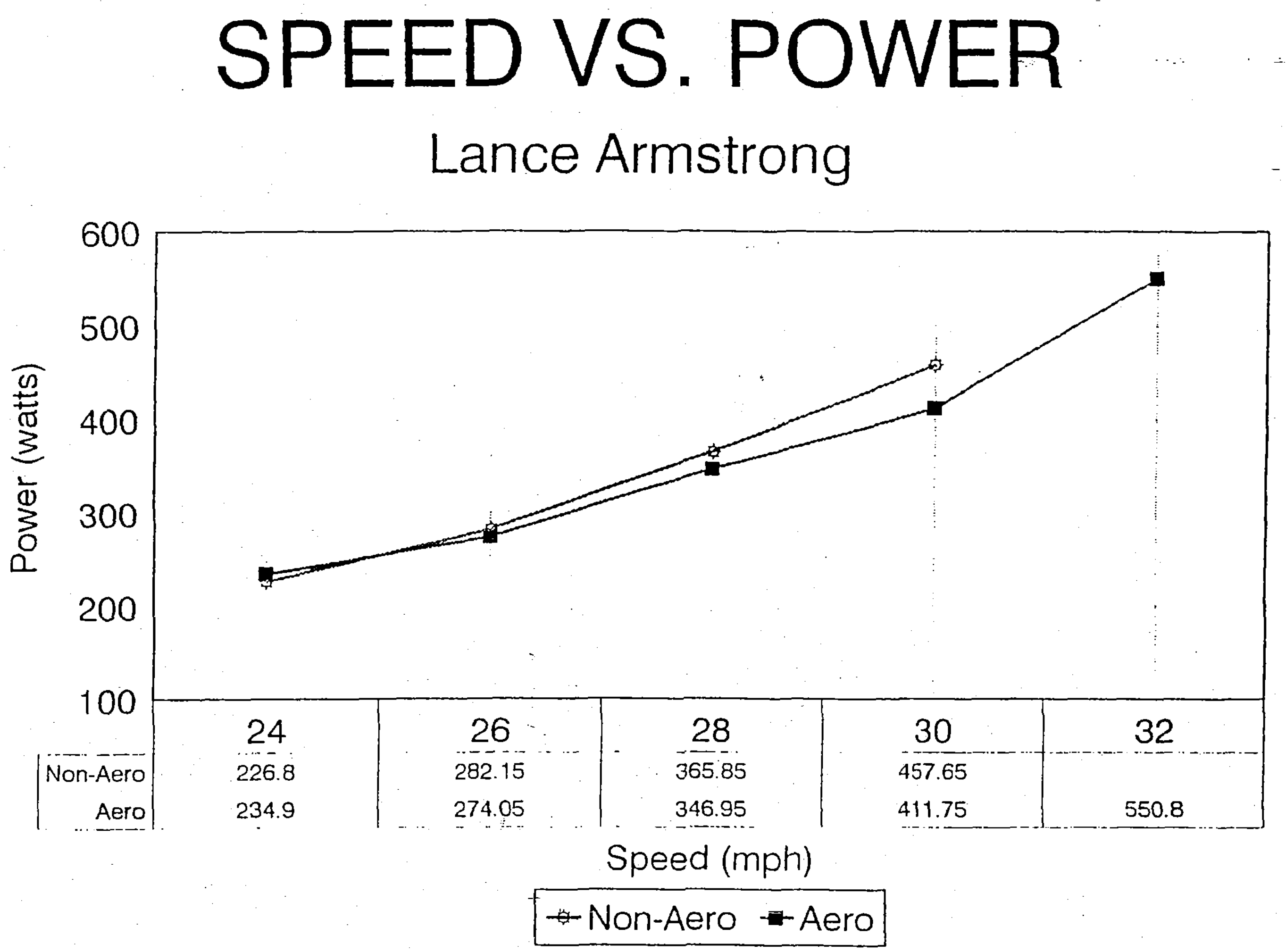


Figure 4: Aerodynamic Position on Bicycle

The image on the left is Lance's normal time-trialing position as observed during his Tour du Pont race and duplicated in the laboratory. The image on the right is Lance's position after he was instructed to adopt a more aerodynamic position (by moving forward on the seat and gripping the clip-ons further forward of the stem). Grid lines behind Lance are 1-inch apart. Superimposed over the images of Lance are his trunk angle, and the contours of his torso and head. To illustrate the difference between positions, the angle and contour lines describing Lance's normal riding position on the left are also superimposed over Lance's new, aerodynamic position shown in the right image. Note the 2-inch lower trunk and head positions, and the flatness of Lance's back.



	24	26	28	30	32
Non-Aero	226.8	282.15	365.85	457.65	
Aero	234.9	274.05	346.95	411.75	550.8

Figure-5: Track Test Data

Bicycle power output is displayed vs bicycle speed in Lance's normal time-trialing position (non-aero) and in a modified geometry position (aero). At 30 mph, power was reduced 46 watts (more than 10 percent) by adopting a more aerodynamic form. At a 400 watt effort level, Lance rode approximately 0.9 mph faster in the aero position. Due to instrumentation errors, power levels are believed to be slightly high (see text), but relationships between the non-aero and aero positions are not affected.

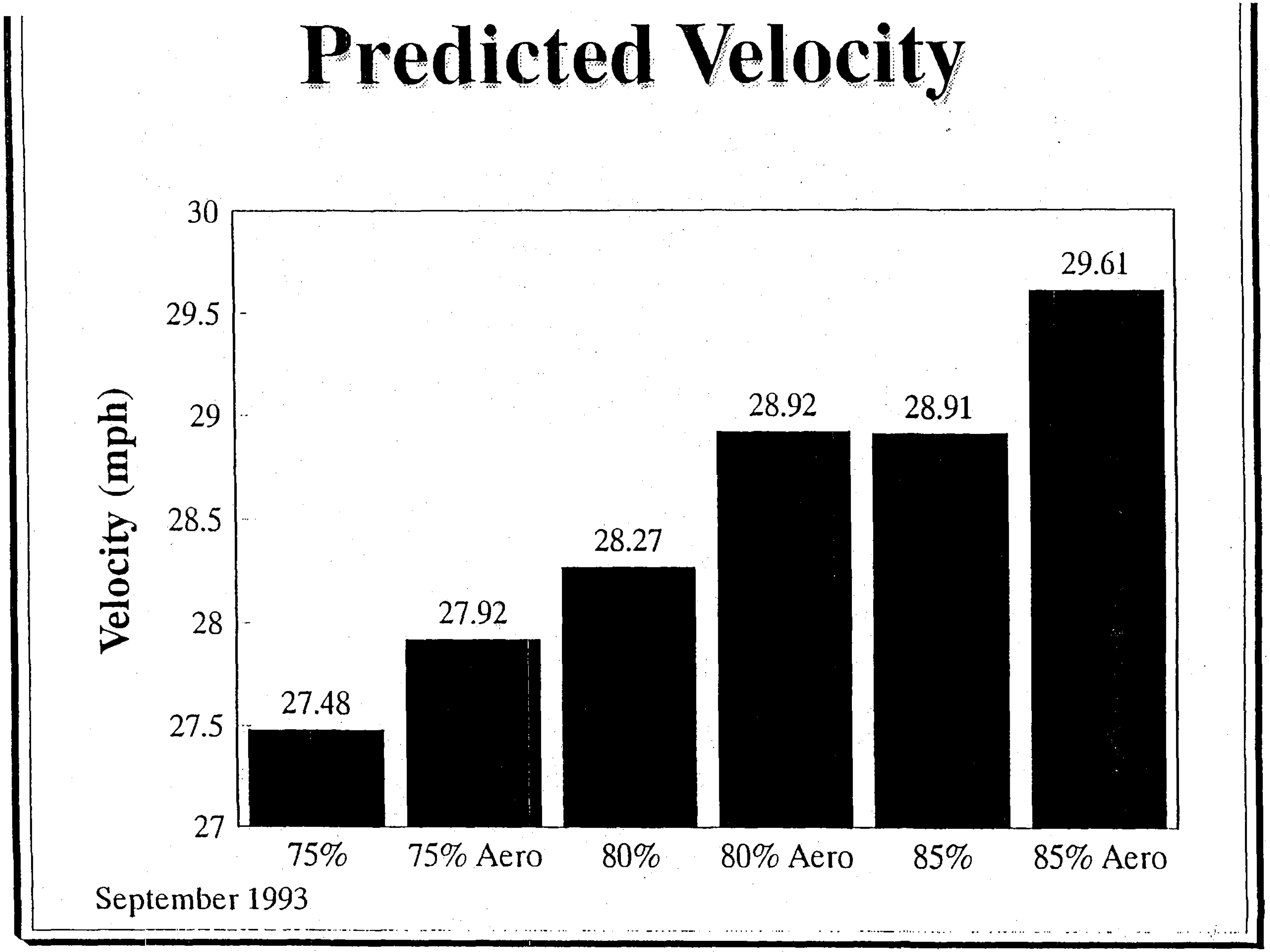


Figure 6: Predicted Velocity

The graph depicts the predicted speeds that could be maintained at threshold levels and compares these data with the speeds obtainable with the application of the aerodynamic modifications. Due to instumentation errors, power levels are believed to be slightly high (see text). The relationships between the non-aero and aero positions are not affected.

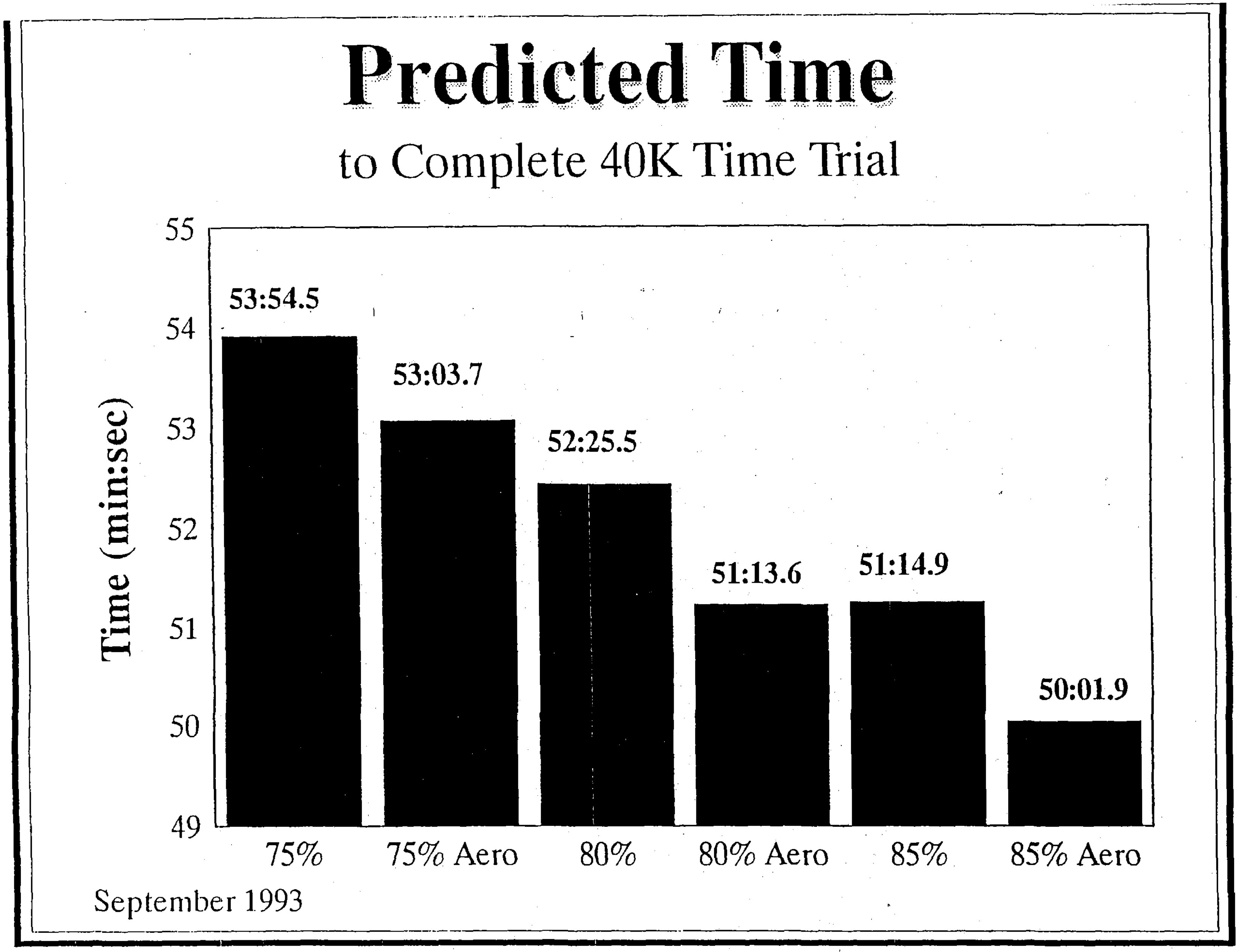
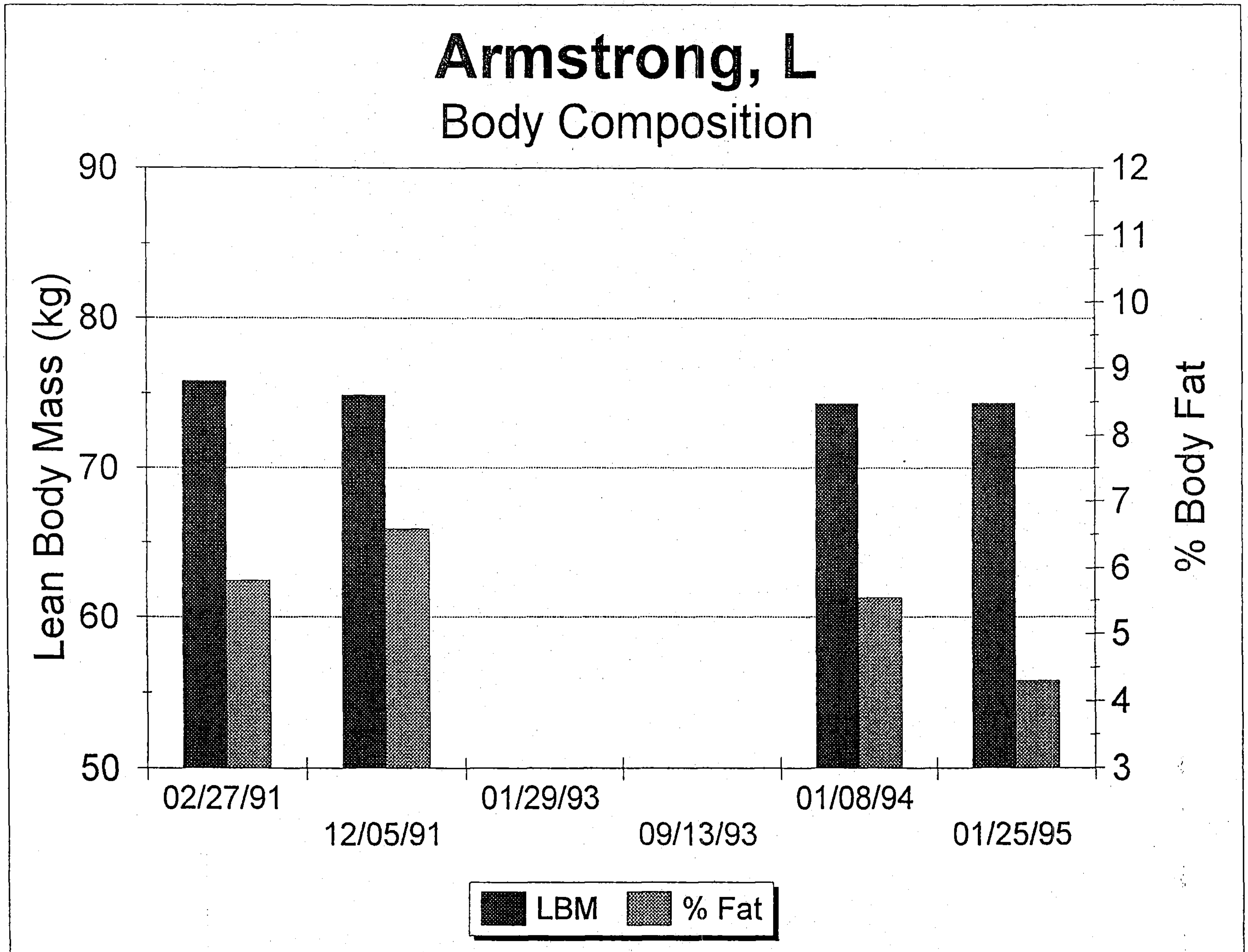


Figure 7: Predicted Time to Complete a 40K Time Trail

Times to complete a 40K time trial were predicted from the threshold power and aerodynamic modification data obtained at the 7-Eleven Velodrome. Riding with the aerodynamic modifications at his current threshold, Lance could reduce his time by 51 seconds. By combining an increase in threshold to 80% of his VO_2 max with the aerodynamic modifications, he could reduce his time to 51:13.6. Due to instumentation errors for power levels (see text) the predicted times may be slightly lower than actual times.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Body Composition
Lean Body Mass (kg)
% Body Fat
90
80
70
60
50
12
11
10
9
8
7
6
5
4
3
02/27/91
12/05/91
01/29/93
09/13/93
01/08/94
01/25/95
LBM
% Fat