ABSTRACT

Title: The Effect of Alcohol on Eye Movements

Researcher: Sarah A. Bigsby

Date Submitted: December 29, 1993

In this study, pursuit eye movements of four volunteer subjects were recorded with an infrared eye movement monitor under conditions similar to the National Highway Traffic safety Administration field sobriety test. These recordings were then analyzed to determine the effect of different blood alcohol concentrations (0-0.08%) on pursuit eye movements. These blood alcohol concentrations were measured with a portable breath tester that is currently being used today by the NHTSA. The effect of different target velocities (10-45 degrees/sec) on pursuit eye movements at specific blood alcohol concentrations was also determined from these recordings. Finally, the angle of onset of horizontal gaze nystagmus at different blood alcohol concentrations was determined by direct observation on a perimeter arc.

The Effect of Alcohol on Eye Movements

METHODS

Pursuit eye movements were recorded by using an infrared eye movement monitor on four subjects. The subjects were given doses of alcohol which produced blood alcohol concentrations of approximately .02, .04, .06, and .08%. In addition, a control was used in which the subjects were given no alcohol and pursuit eye movements were recorded as baseline data. The pursuit stimulus was presented at six different velocities: 10, 15, 20, 25, 30, and 45 degrees/sec. Blood alcohol concentrations were determined with the Alco-Sensor™ portable breath tester, which was capable of reading blood alcohol concentrations to .001%. Following presentation of the pursuit stimuli, the onset of horizontal gaze nystagmus for each eye was determined using a perimeter arc by direct observation.

Each subject participated in six different testing sessions on different days. At each session a randomly determined blood alcohol concentration unknown to the subject was used. Experimental sessions occured in the afternoon and each subject was instructed not to consume any alcohol or take any stimulant, depressant, or tranqualizer within a 24 hour period prior to the session. These subjects were also instructed to eat a light lunch before coming to each session. These conditions were the same as those used by the State Police in their controlled drinking exercises. Blood alcohol concentrations were produced using a predetermined dose of 50% ethyl alcohol mixed with 16 ounces of orange juice for each subject. The predetermined alcohol dose was measured based on the equation:

#ml=(400) (BAC) (Body weight-lbs) / (% alcohol)[1]

Before any eye movements were recorded and any alcohol was given the eye movement monitor was calibrated. A protable breath tester reading was taken, and horizontal gaze nystagmus was measured. This ensured that each subject started at zero blood alcohol concentration and also supplied us with baseline data to use as a control. Each of the subjects were then given 15 minutes after finishing the drink. This 15 minute time elapse was required for residual alcohol to leave the mouth thus reducing the chance of recording a falsely high blood alcohol concentraiion reading. Portable breath testings were taken every 5 minutes after the first reading until the reading stabilized. Once this blood alcohol concentration stabilized, eye movement recordings were then measured with the infrared eye monitor.

A maximum of 15 minutes was required to complete the eye movement recordings and measured the horizontal gaze nystagmus for each subject in each session. Since alcohol is metabolized by the body at a rate of .01% blood alcohol concentration per hour regardless of the initial blood alcohol concentration, little change in blood alcohol concentraiion occured to contaminate the results of the data over the collection period.

The pursuit stimulus was a moving spot on a TV screen. The spot was presented 5 degrees above the eye level and moved horizontally across the screen. The spot moved through a total of 110 degrees on the screen (55 degrees each side of the midpoint) which ensured that the stimulus would go beyond the normal limit of horizontal eye movement. This target was presented straight ahead and stationary at first. The subject was then instructed to follow the target with his eyes when the spot began to move. The velocities were then chosen randomly and two complete cycles were recorded using a strip-chart recorder. The spot was centered for each target velocity and two cycles of pursuit movements were recorded for each of six target velocities. Following these pursuit eye movement recordings, horizontal gaze nystagmus was determined monocularly using direct measurement with a perimeter arc.

DATA ANALYSIS

Endpoint Nystagmus

At the maximum extent of eye motion about half the population will show a slight but distinct jerkiness of eye position. This nystagmoid motion is called endpoint or gaze evoked nystagmus. Alcohol in the bloodstream causes this enpoint nystagmus to occur at angular extents less than the normal maximum. The maximum extent of a horizontal eye rotation outward toward the ear is about 50 degrees. However, with increasing blood alcohol concentrations, the horizontal gaze nystagmus begins closer to the midline with greater amplitude and frequency.

According to the 1983 article, Field Evaluation of a Behavioral Test Battery for DWI, procedures were established by the National Highway Traffic Safety Administration for road-side sobriety testing of drivers by police officers on the basis that a liner relation between blood alcohol concentration and angle of onset of horizontal gaze nystagmus exists. This relation as determined by NHTSA is;BAC=50 - angle of onset / 100.[1]

However, application of this formula in our study resulted in findings which would have been less warmly received by police officers interested in a DWI arrest. In short, the NHTSA formula was devised to result in a higher blood alcohol concentration than the findings which occurred with our test subjects. I.E., the resulting tes subject formula was as follows;

Kevin; 34.5 endpoint at actual BAC of .04%
NHTSA; 35.5 endpoint at calculated BAC of .155%

Therefore, while the data on each subject confirms the existence of the NHTSA proposed linear relationship in which the onset of nystagmus begins closer to midline with increasing blood alcohol concentration, our data reveals that there is no set threshold of onset of nystagmus related to blood alcohol concentration but rather the threshold seems to vary in each subject.

When the average onset of nystagmus of all four subjects was plotted on the graph and individual variance was removed, again, the graph showed a more definite linear, but, no common threshold of blood alcohol concentration was noted in this average of the four subjects.

Pursuit Eye Movements

Smooth pursuit eye movements occur when a person follows an object moving within certain angular velocity limits. A pursuit eye movement is defined to have a 125 msec latent period and an angular velocity equal to the target velocity up to target velocities near 50 degrees/sec. With alcohol in the blood stream, the following movement is no longer smooth but is broken up by rapid eye movements or "saccades".[1]

In this study, the average of all four subjects on number of saccades/cycle at each blood alcohol concentration were calculated and plotted on the graph. The black line on each graph represents the blood alcohol concentration we hoped to establish and the red line on each graph represents the actual average blood alcohol concentration achieved. Each graph shows that between .02% and .04% blood alcohol concentration, there is an increase in the number of saccades/cycle. This incicates that the smooth pursuit eye movement no longer is smooth but rather broken up at blood alcohol concentrations between .02% and .04% and between 0 and .029%.

The graphs also show that the number of saccades continues to increase from .04% to .06% for ball speeds of 10, 15, 20, and 25 degrees per second. However ball speeds of 30 and 45 show great variability in the number of saccades between .04% and .06%. This variability is probably due to the limits of velocity of the smooth pursuit movement being reached and thus is difficult to determine if the saccades are due to the blood alcohol concentration increase or the pursuit's natural limits.

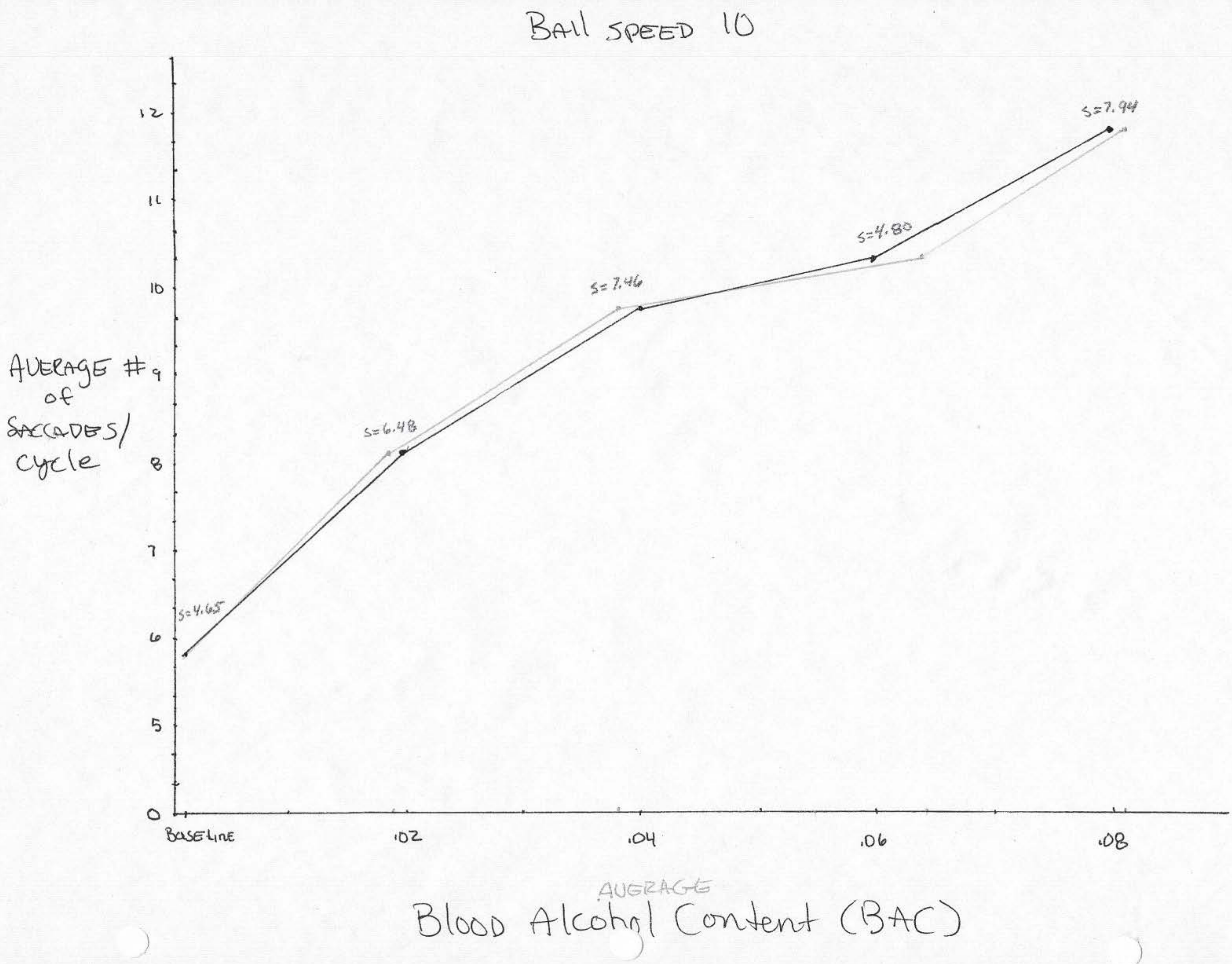
Of particular interest is the ball speed of 10 which shows a consistent direct correlation between the number of saccades per second and the increase of blood alcohol concentration. Because of the near abscence of variation in direct correlation of increasing saccades and blood alcohol concentration, this measurement is clearly the most accurate for road-side sobriety testing by police officers. This data also indicated that unless a mechanical device is used to eliminate human error, it would be difficult to attach an <u>accurate</u> result from officers attempting to duplicate the exact ball speed of 10 at a road side test circumstance. Howerver, an <u>estimate</u> could be made by moving the stimulus at nearly an optimum rate.

Standard deviations were calculated for each BAC. Theses are shown above the small number of subjects. As more subjects are added, the standard deviations should decrease allowing for statistically valid conclusions.

In summary, the data indicates that a linear relation exists between BAC and breakdown of pursuit eye movements. Because of the small number of subjects and the resultant large standard deviations, no definite conclusions can be made regarding exact predictions of BAC and breakdown of pursuit movements. The data suggests that target velocities of 10 or 15 degrees per second may be optimum in prediciting blood alcohol levels.

REFERENCE

1. King, Vincent, "The Effect of Alcohol on Eye Movements." Grant study, Ferris University, 1986.



BALL SPEED 10
AVERAGE # of SACCADES/ cycle
0
5
6
7
8
9
10
11
12
s=4.65
s=6.48
s=7.46
s=4.80
s=7.94
BASELINE
.02
.04
.06
.08
AVERAGE
Blood Alcohol Content (BAC)

BAC (.06)
SACCADES / cycle

Kevin 17.46
Scott 7.43
Kyle 8.0
Sam 8.0

AVG = 10.22

Ball speed S=4.8
10

BAC (.08)
SACCADES / cycle

Kevin 22.85
Scott 11.43
Kyle 6.0
Sam 7.42

AVG = 11.925

Ball speed S = 7.94
of
10

Baseline
SACCADES / cycle

Kevin	12	AVG = 5.75
Scott	4	
Kyle	1	
Sam	4	STD DEV: 4.65

Ball speed
10

BAC (.02)
SACCADES / cycle

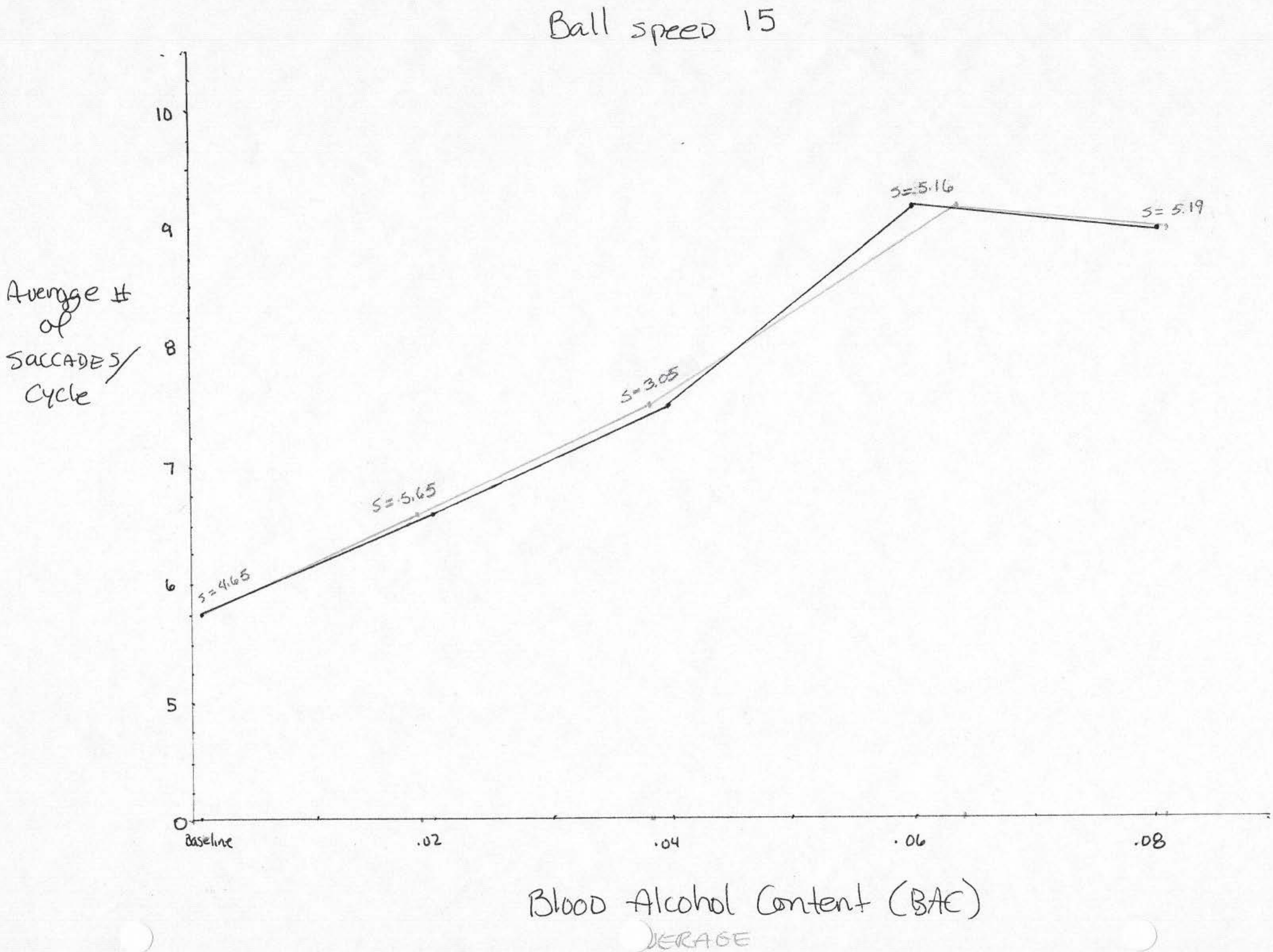
Kevin	15.43	AVG = 8.17
Scott	11.43	
Kyle	3.0	
Sam	2.8	$s^2 = 6.48$

Ball speed
10

BAC (.04)
SACCADES / cycle

Kevin	20.6	AVG 9.76
Scott	8.8	
Kyle	5.0	
Sam	4.67	$s = 7.46$

Ball speed
10



Ball speed 15
Average # of SACCADES/ Cycle
10
9
8
7
6
5
0
Baseline
.02
.04
.06
.08
s = 4.65
s = 5.65
s = 3.05
s = 5.16
s = 5.19
Blood Alcohol Content (BAC)

Base line
SACCADES / cycle

Kevin	12	AVG = 5.75
Scott	6	
Kyle	~~8~~ 1	
Sam	4	

S = 4.65

Ball speed of (10) was used for 15 data

BAC (.02)
SACCADES / cycle

Kevin	14.29	AVG = ~~[illegible]~~ 6.61
Scott	7.42	
Kyle	2.40	
Sam	2.33	

S = 5.65

Ball speed 15

BAC (.04)
SACCADES / cycle

Kevin	12.0	AVG = 7.5
Scott	4.9	
Kyle	5.6	
Sam	5.6	

S = 3.05

Ball speed 15

Bac (.08)
SACCADES / cycle

Kevin	16.00	AVG = 8.97
Scott	9.71	
Kyle	4.57	
Sam	5.6	

s = 5.19

Ball speed (15)

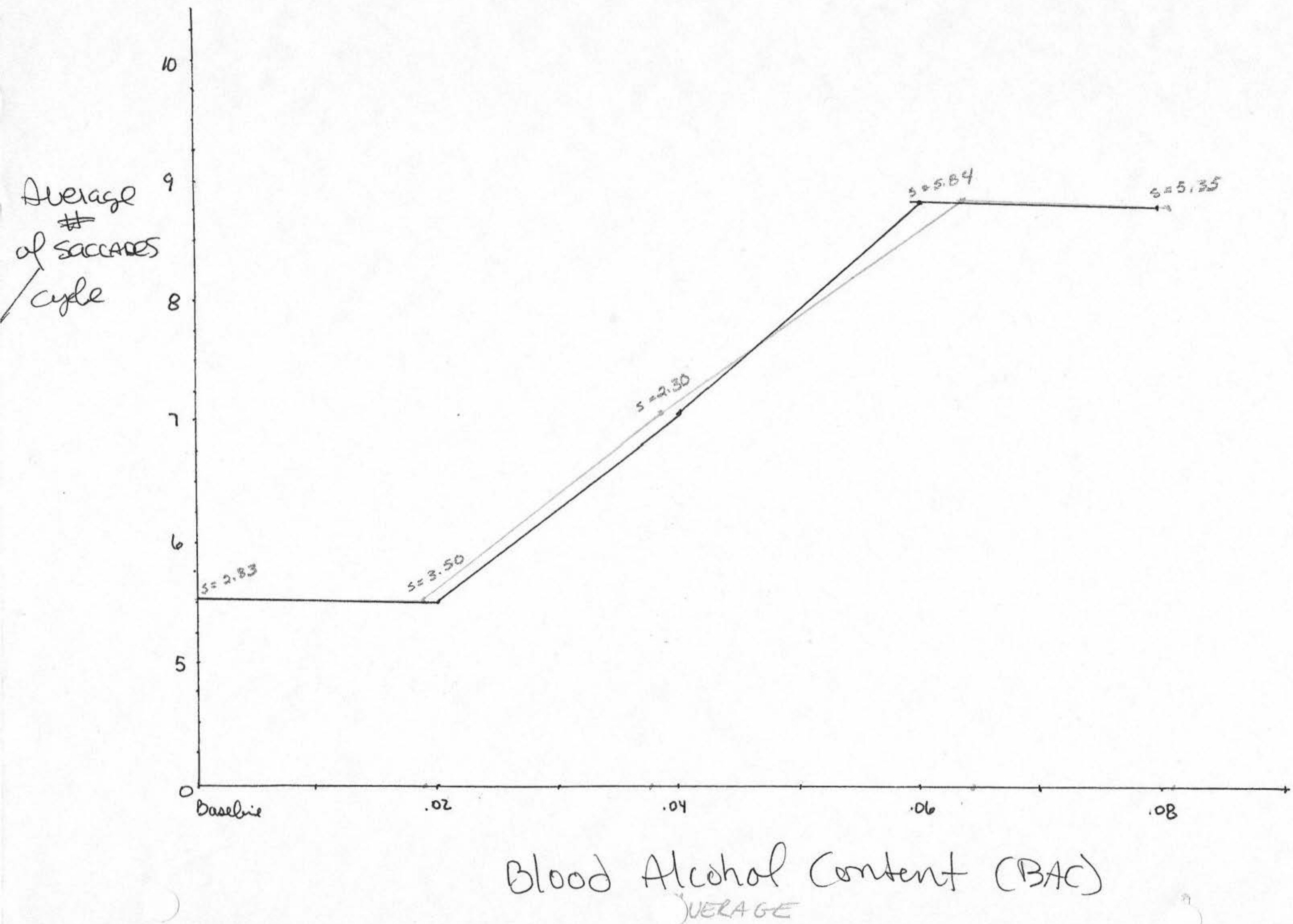
BAC (.06)
SACCADES / cycle

Kevin	16.73	AVG = 9.2
Scott	8.36	
Kyle	6.00	
Sam	5.71	

s = 5.16

Ball speed (25)

Ball speed 20



Baseline

\# SACCADES / cycle

Kevin	8.5
Scott	7.33
Kyle	2.4
Sam	4.0

AVG = 5.56

S = 2.83

Ball Speed
20

BAC (.02)

\# SACCADES / cycle

Kevin	10.4
Scott	5.6
Kyle	2.8
Sam	3.2

AVG = 5.5

S = 3.50

Ball Speed
20

BAC (.04)

\# SACCADES / cycle

Kevin	10.4
Scott	5.0 ~~[illegible]~~
Kyle	6.8
Sam	6.4

7.15

AVG = 7.15

S = 2.30

BALL Speed
20

BAC (.06)
#SACCADES / cycle

Kevin	17.60	AVG = 8.89
Scott	6.8	
Kyle	5.45	
Sam	5.71	

S = 5.84

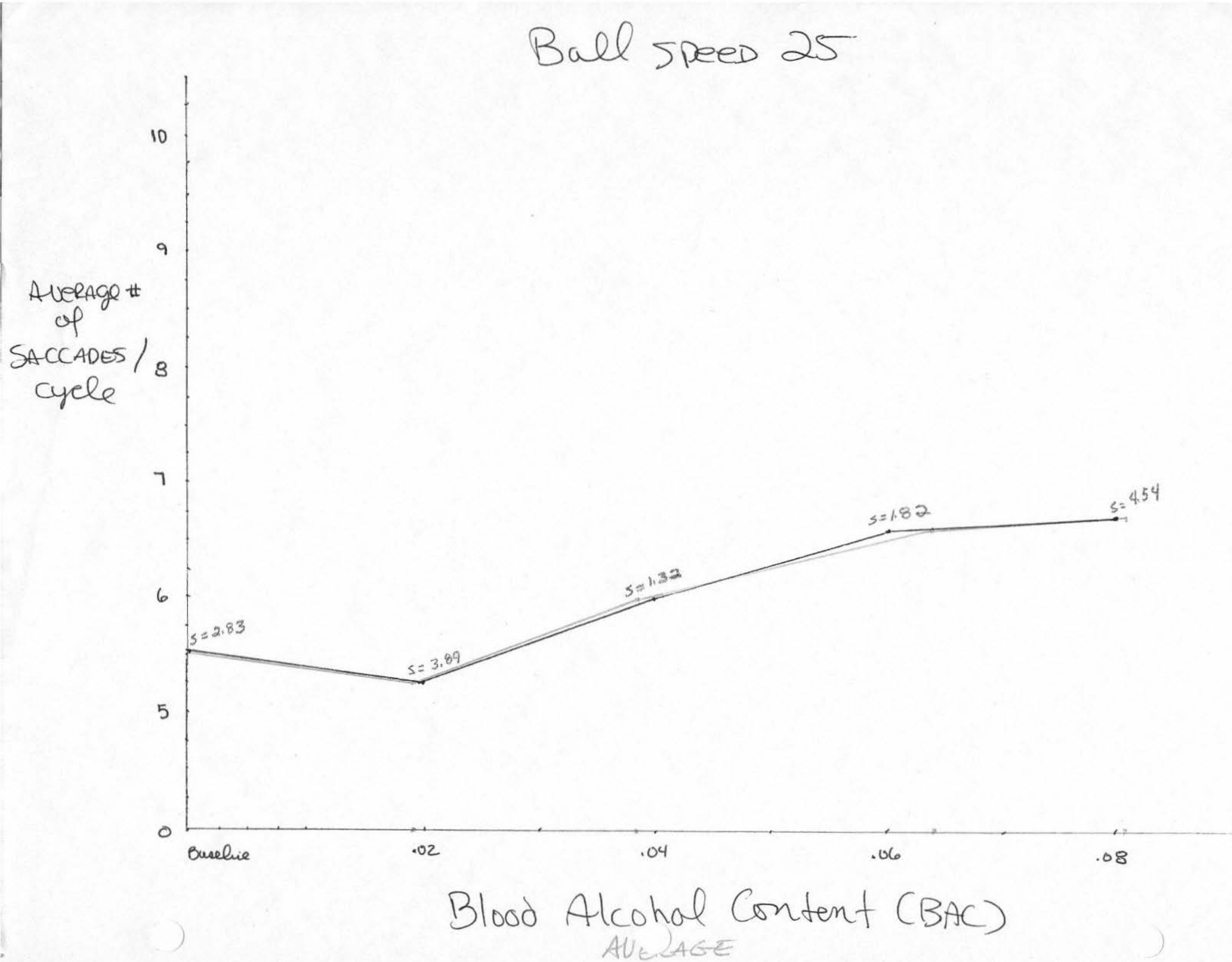
Ball speed
20

BAC (.08)
SACCADES / cycle

Kevin	16.00	AVG = 8.83
Scott	9.82	
Kyle	5.09	
Sam	4.4	

S = 5.35

Ball speed
20



Ball Speed 25
Average # of Saccades / cycle
10
9
8
7
6
5
0
s = 2.83
s = 3.89
s = 1.32
s = 1.82
s = 4.54
Baseline
.02
.04
.06
.08
Blood Alcohol Content (BAC)
AVERAGE

Baseline
SACCADES / cycle

Kevin	8.5	AVG = 5.56
Scott	7.33	
Kyle	2.4	
Sam	4.0	

S = 2.83

Ball speed of 20 was used for 25

BAC (.02)
SACCADES / cycle

Kevin	9.2	AVG = 5.25
Scott	8.0	
Kyle	1.82	
Sam	2.0	

Ball speed 25

S = 3.89

BAC (.04)
SACCADES / cycle

Kevin	5.45	AVG = 6.03
Scott	8.0	
Kyle	5.33	
Sam	5.33	

S = 1.32

Ball Speed 25

BAC (.06)
SACCADES / cycle

Kevin	8.36	AVG = 6.62
Scott	8.0	
Kyle	5.33	
SAM	4.8	

S = 1.82

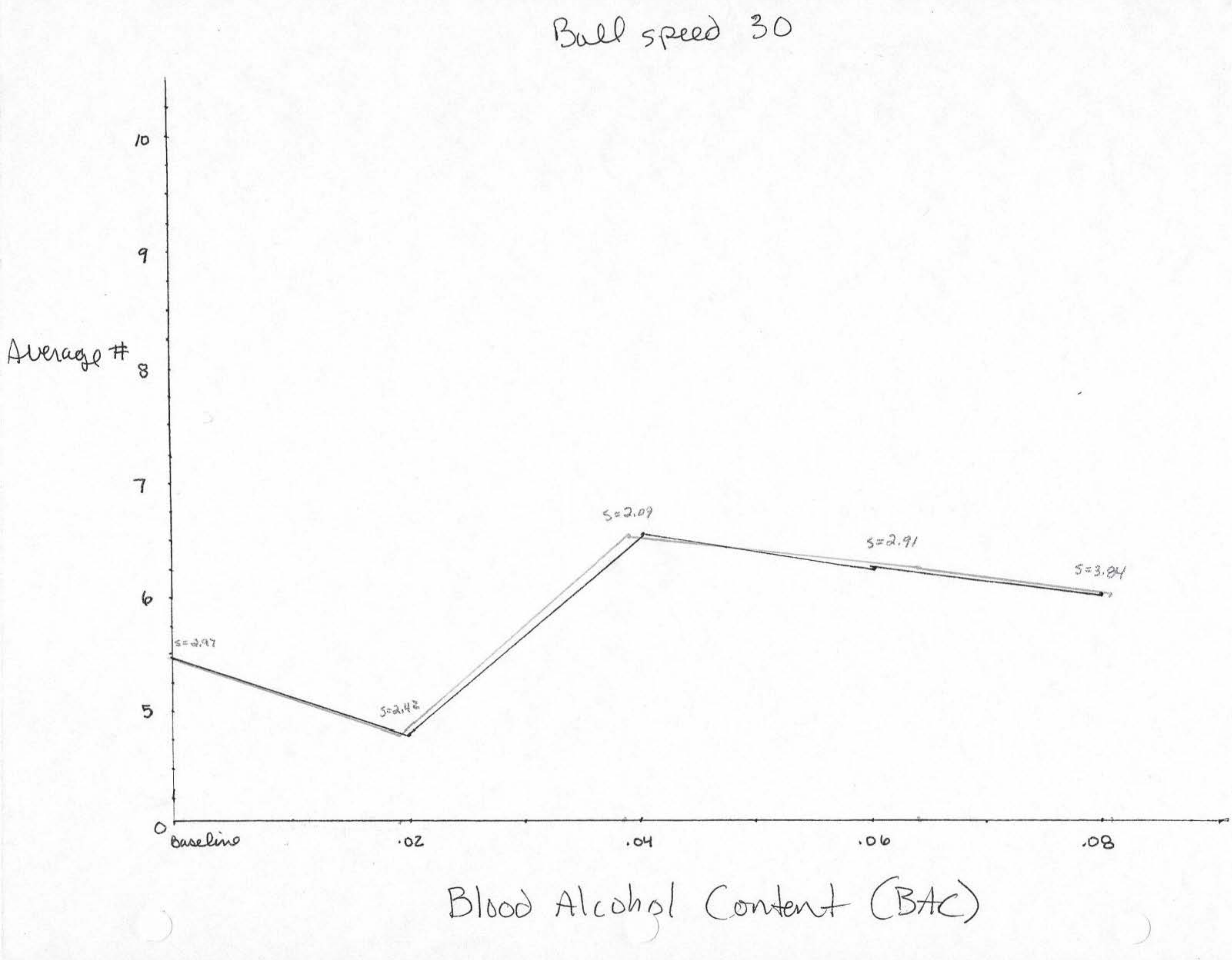
Ball speed
25

BAC (.08)
SACCADES / cycle

Kevin	12.0	AVG = 6.7
Scott	8.8	
Kyle	4.0	
Sam	2.0	

S = 4.54

Ball speed
25


Ball speed 30
Average #
10
9
8
7
6
5
0
Baseline
.02
.04
.06
.08
s=2.97
s=2.42
s=2.09
s=2.91
s=3.84
Blood Alcohol Content (BAC)

Baseline
SACCADES/cycle

Kevin	9.0	AVG = 5.45
Scott	6.8	
Kyle	3.2	
Sam	2.8	

S = 2.97

Ball speed
30

BAC (.02)
SACCADES /cycle

Kevin	8.0	AVG = 4.77
Scott	5.2	
Kyle	2.66	
Sam	3.2	

Ball speed S = 2.42
30

BAC (.04)
SACCADES /cycle

Kevin	9.6	AVG = 6.57
Scott	5.6	
Kyle	4.67	
Sam	6.4	

Ball speed S = 2.09
30

BAC (.06)
SACCADES / cycle

Kevin	9.82	AVG = 6.26
Scott	6.80	
Kyle	5.6	
SAM	2.8	

S = 2.91

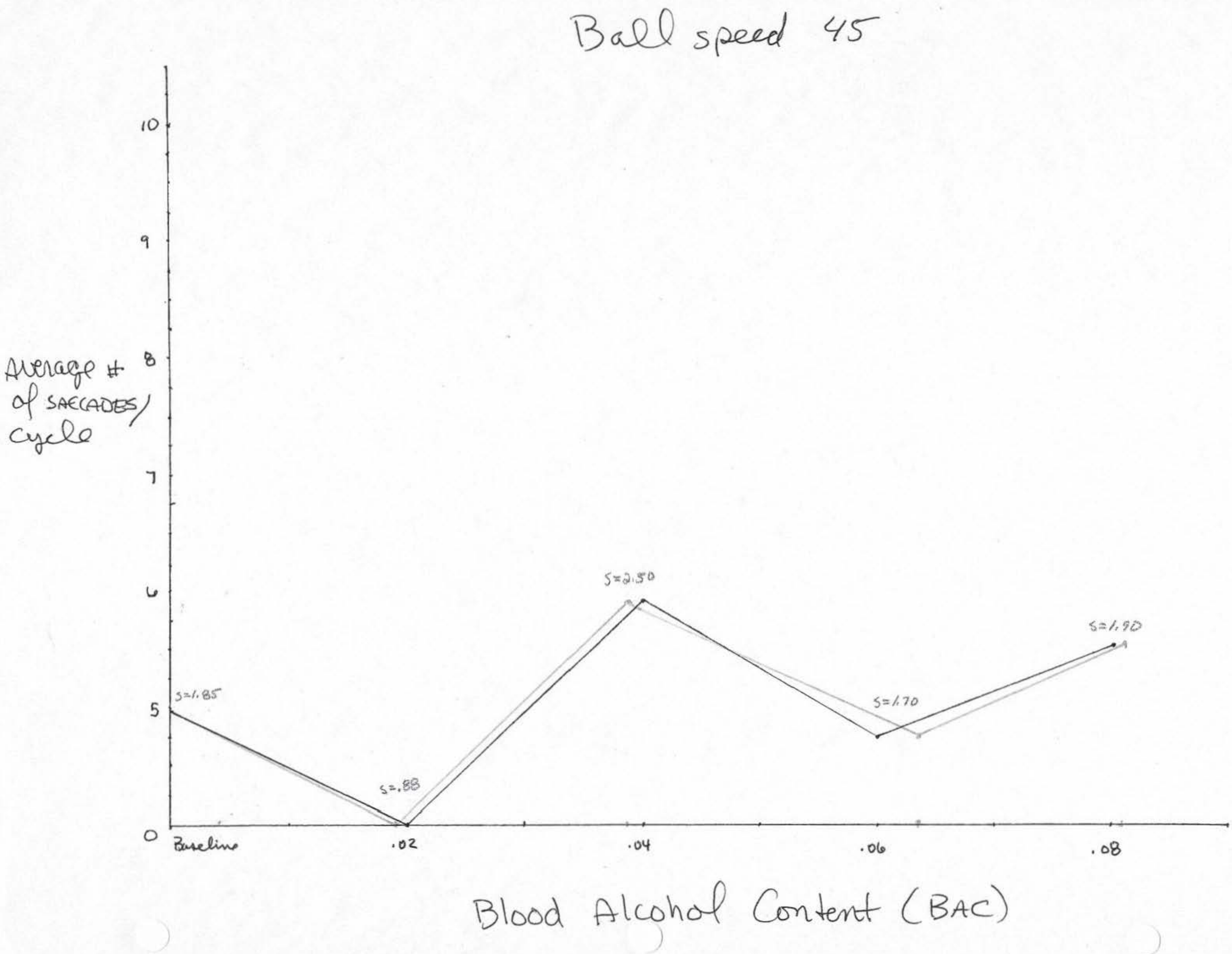
Ball speed
30

BAC (.08)
SACCADES / cycle

Kevin	10.4	AVG = 6.0
Scott	8.0	
Kyle	3.2	
SAM	2.4	

S = 3.84

Ball speed
30



Ball speed 45
Average # of SACCADES/ cycle
10
9
8
7
6
5
0
s=1.85
s=.88
s=2.50
s=1.70
s=1.90
Baseline
.02
.04
.06
.08
Blood Alcohol Content (BAC)

Baseline
SACCADES / cycle

Kevin	5.67
Scott	7.20
Kyle	3.0
Sam	4.0

AVG = 4.97

S = 1.85

Ball speed 40 was used for 45

BAC (.02)
SACCADES / cycle

Kevin	5.20
Scott	3.20
Kyle	3.60
SAM	3.67

AVG = 3.92

S = .88

Ball speed 45

BAC (.04)
SACCADES / cycle

Kevin	9.50
Scott	5.0
Kyle	5.60
SAM	3.67

AVG = 5.94

S = 2.50

Ball speed 45

BAC (.06)
SACCADES / cycle

Kevin	7.27	AVG = 4.74
Scott	4.0	
Kyle	4.0	
Sam	3.67	

S = 1.70

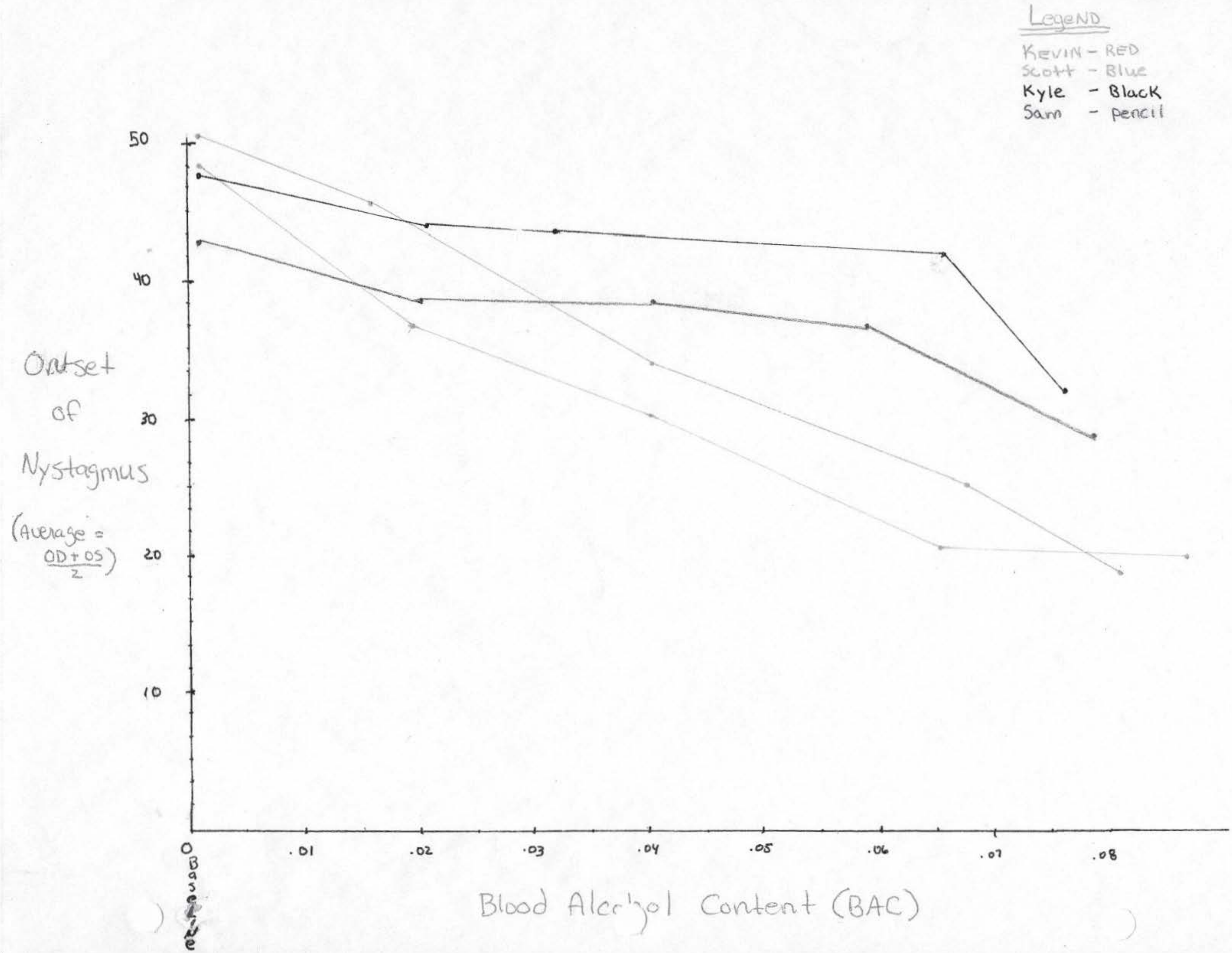
Ball speed
45

BAC (.08)
SACCADES / cycle

Kevin	7.67	AVG = 5.62
Scott	6.8	
Kyle	4.0	
Sam	4.0	

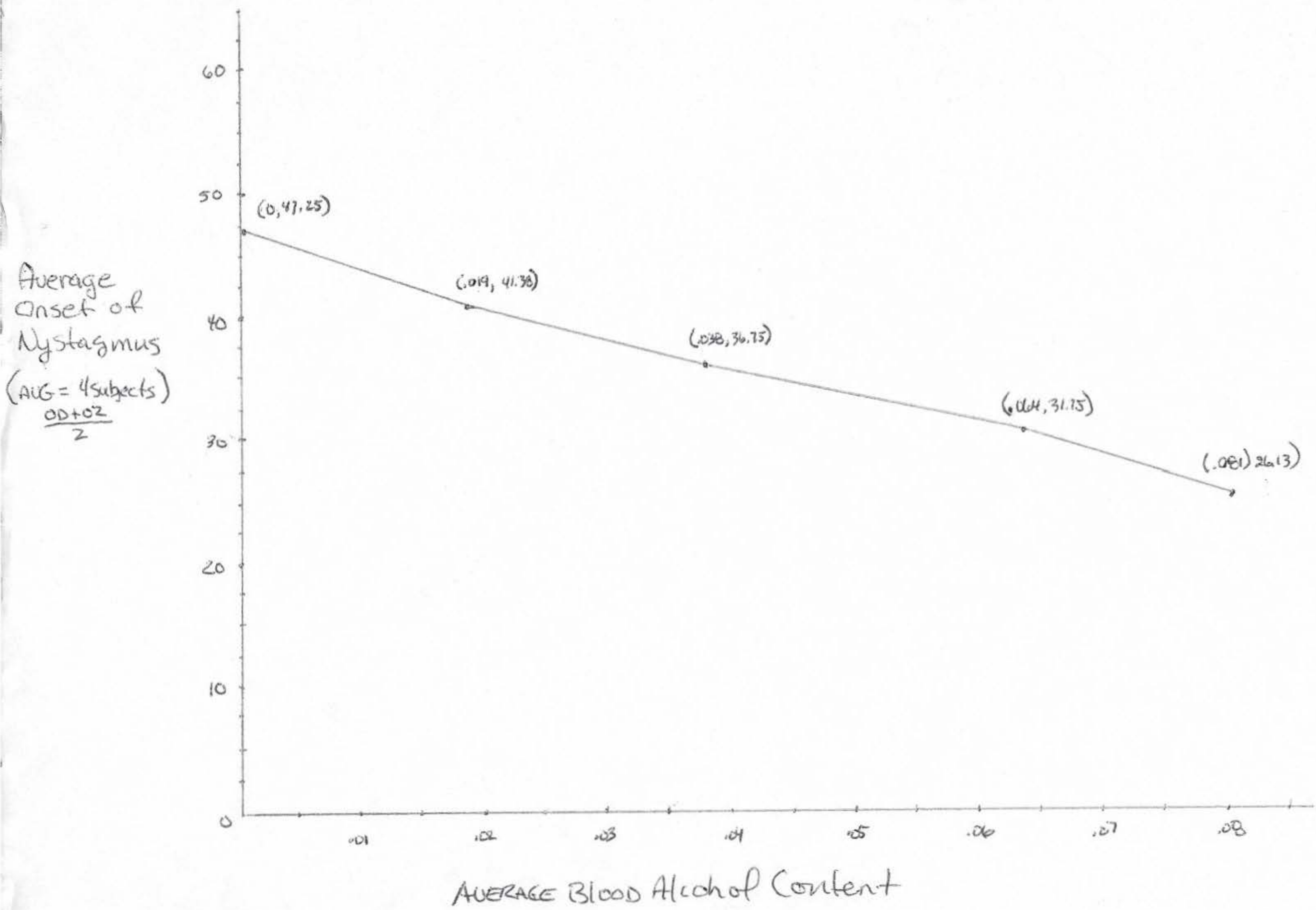
S = 1.90

Ball speed
45



LegeND
Kevin - RED
Scott - Blue
Kyle - Black
Sam - pencil
50
40
30
20
10
0
Baseline
.01
.02
.03
.04
.05
.06
.07
.08
Onset of Nystagmus
(Average = (OD + OS)/2)
Blood Alcohol Content (BAC)

EFFECT OF ALCOHOL ON EYE MOVEMENTS



BAC	Level	Nystagmus OD	Nystagmus OS	Ave
Kevin (.016)	.02	44	49	= 46.5
(?) Scott (.019)	.02	43	32	= 37.5
Kyle (.021)	.02	45	42	= 43.5
Sam (.020)	.02	36	40	= 38.0
AVG = (.019)		(42)	(40.75)	= (41.375)
Kevin (.04)	.04	30.5	38.5	= 34.5
Kyle (.031)	.04	44	45	= 44.5
Scott (.04)	.04	24	36	= 30
Sam (.04)	.04	36	40	= 38
AVG = (.038)		(33.63)	(39.88)	(36.75)
Kyle (.065)	.06	46	39	= 42.5
Scott (.065)	.06	23	19	= 21
Kevin (.068)	.06	24	28	= 26
Sam (.057)	.06	34	41	= 37.5
AVG = (.064)		(31.75)	(31.75)	(31.75)
Kevin (.081)	.08	19	20	= 19.5
Kyle (.076)	.08	36	28	= 32
Scott (.089)	.08	23	20	= 21.5
Sam (.079)	.08	35	28	= 31.5
AVG = (.081)		(28.25)	(24)	(26.13)

~~Base~~

Baseline Data	OD	OS	
Scott	41	55	= 48
Kevin	54	47	= 50.5
Kyle	45	50	= 47.5
Sam	43	43	= 43
AVG =	(45.75)	(48.75)	(47.25)

41.375