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ESH

Can We Trust Ambulatory Blood Pressure Monitors? Approved Monitor Underestimates Diastolic Pressure & Misclassifies Patients

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MENS AGITAT MOLEM

BACKGROUND

1. Health-care providers & clinicians urged to consider advantages of using 24-hr ABPM.
2. ABPMs theoretically appealing – up to 200 values ≤ 24 hr
    a. refine classification of suspected hypertensives,
    b. establish diurnal impact of treatments &
    c. tailor specific plans for optimizing BP.
3. Each step is entirely contingent upon obtaining data that is both accurate & reliable.
4. International (ESH, BHS) & US national (AAMI) approval protocols require testing only for subjects who are seated, yet ABPMs that achieve a passing grade are deemed accurate & reliable over 24-hr when patients assume multiple postures.

U.S. National Library of Medicine Database
January 1, 1988 – December 1, 2008
www.ncbi.nlm.nih.gov

- 4579 articles with key words *ambulatory blood pressure*
- 91 (~ 2%) contained key word *validation*
- 17 (~ 0.4%) classified as true validation studies
- 3 studies measured all postures for all subjects
- 12 of 19 ABPMs currently available are recommended for use, yet only 2 have been tested for a variety of postures
- 1 ABPM is approved for multiple body positions

www.dableducational.org

KEY QUESTIONS

1.

If ABPM accuracy & reliability differ based on posture, could this lead to errors in classifying patients & in comparing data?

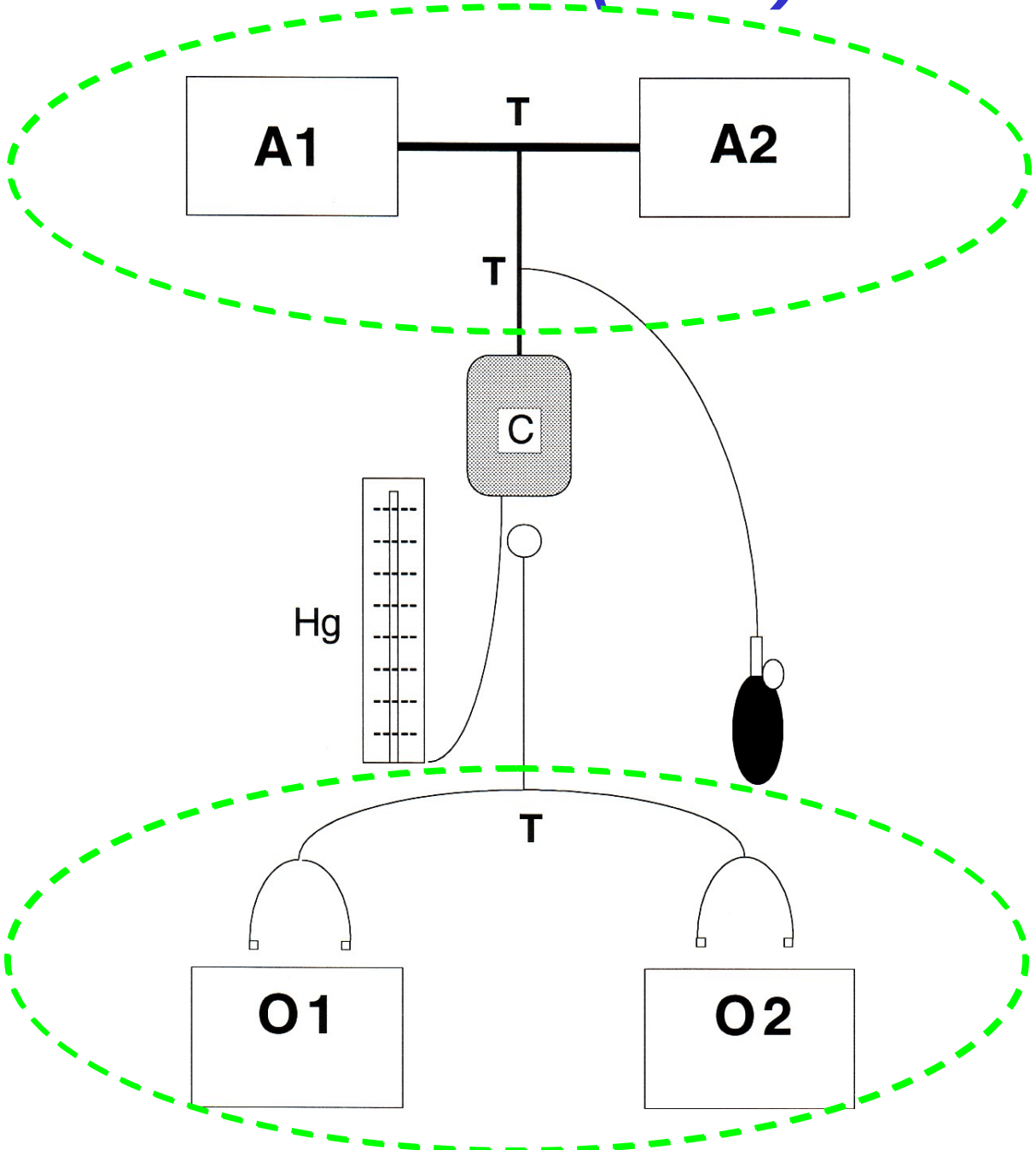
2.

How do two approved, identical ABPMs differ in assessing same arm BPs simultaneously in the lab & in the field?

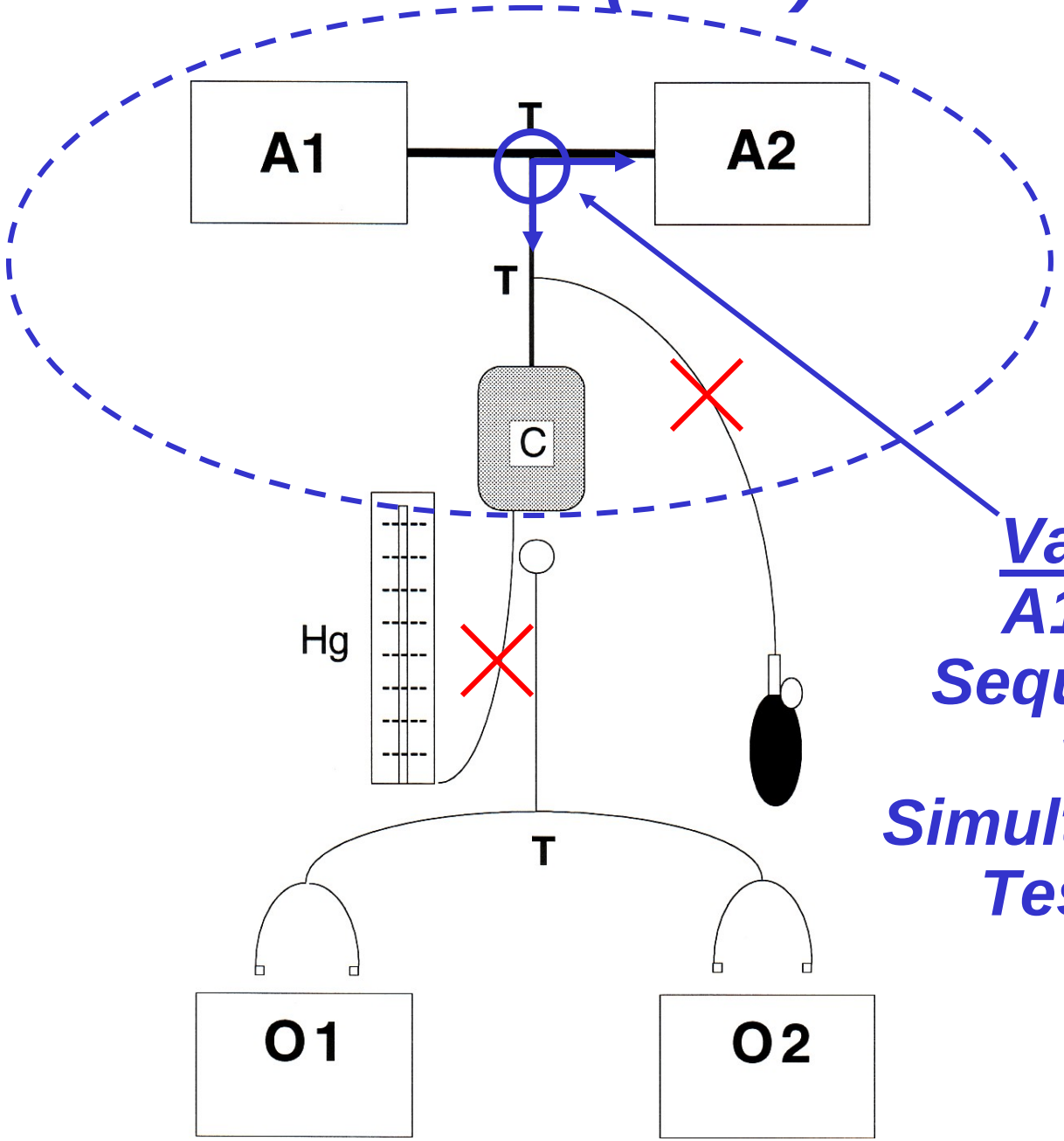
3.

How do ABPMs differ from clinicians using a Hg column when assessing subjects who assume multiple postures?

Dual Monitor Protocol (DMP): Lab + Field

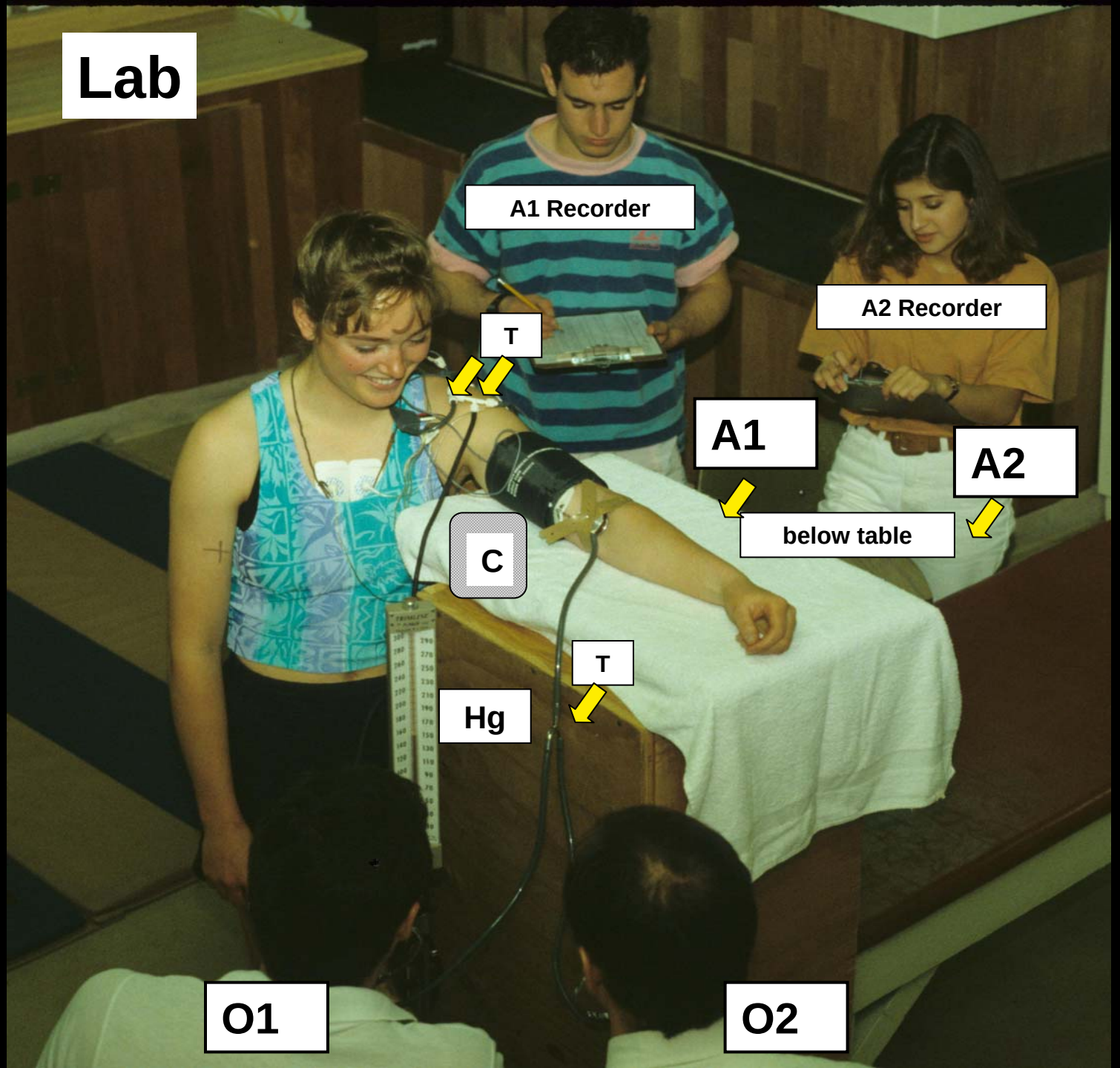


Dual Monitor Protocol (DMP): Lab + Field



Field

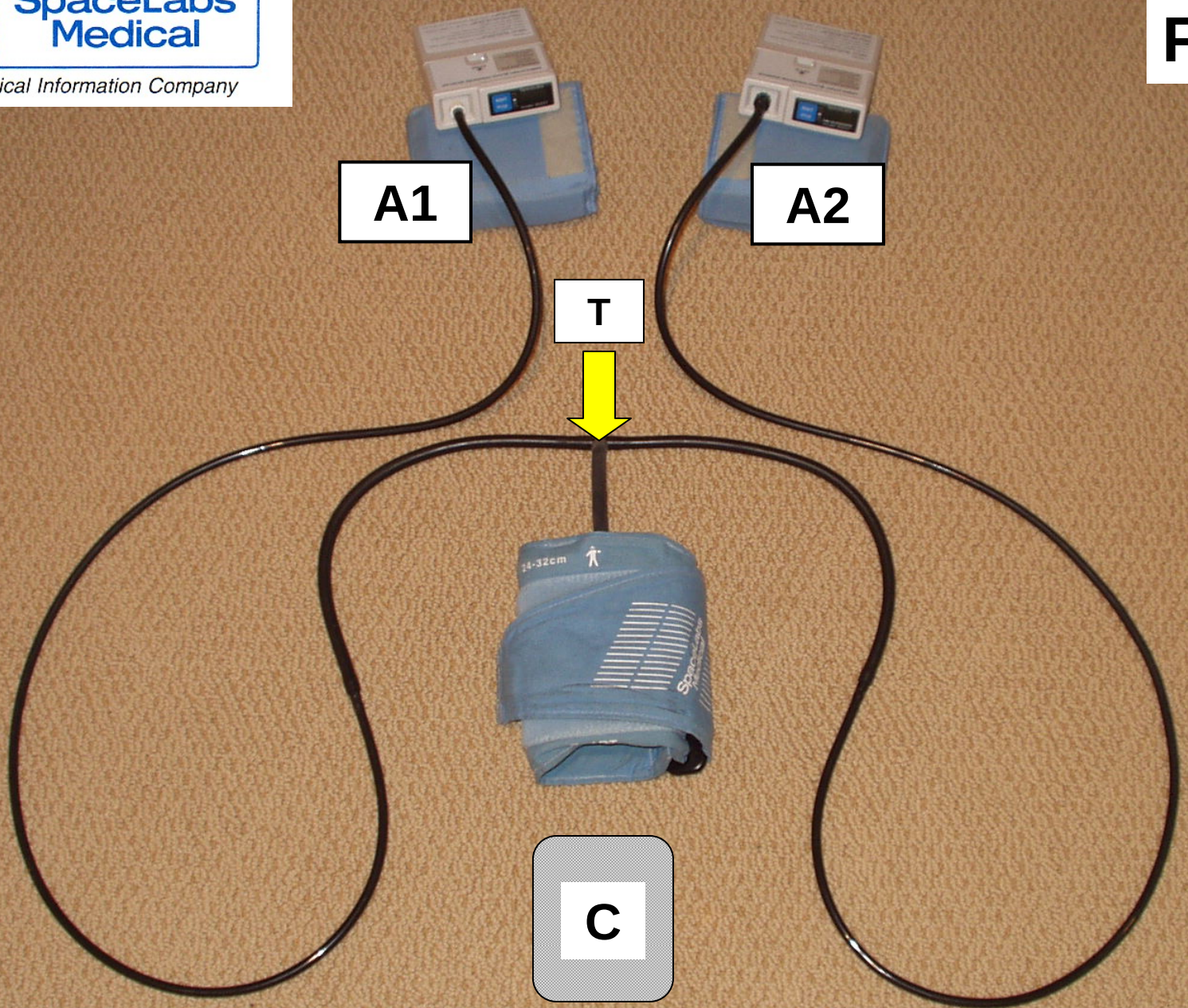
Valve:
A1-A2
Sequential
vs
Simultaneous
Testing


Lab
A1 Recorder
A2 Recorder
T
A1
A2
below table
C
T
Hg
O1
O2

SpaceLabs Medical

The Clinical Information Company

Field



Results Presented Today

Subjects	*Gender*	*Age*
1. 1 Labile HTN	♂	35 yr
2. 15 Normotensives	8 ♀ 7 ♂	24 ± 5 yr
3. 14 Hypertensives	8 ♀ 6 ♂	50 ± 14 yr
4. 11 1^0 ETOH	2 ♀ 9 ♂	38 ± 9 yr

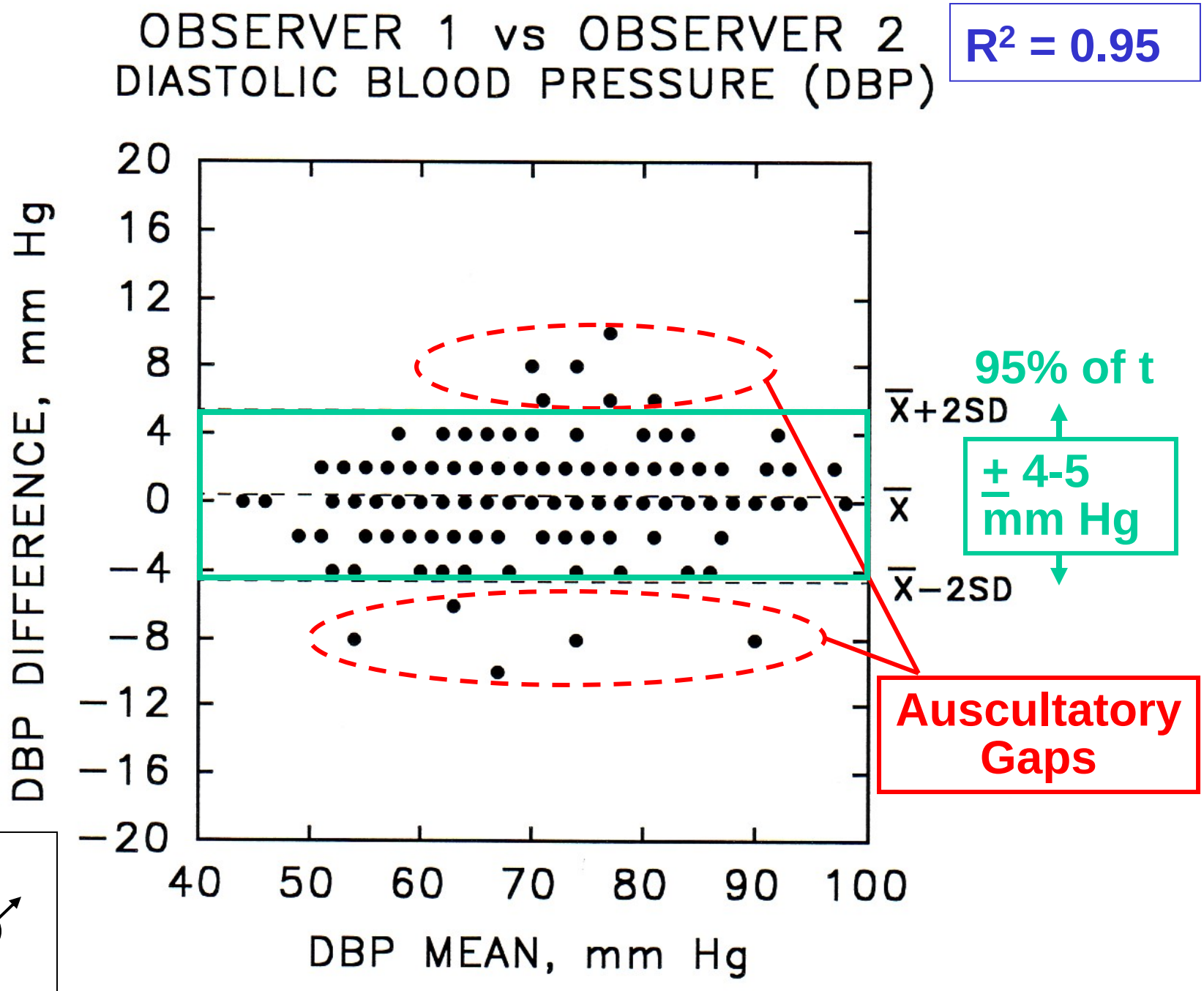
Original Dual Monitor Field Protocol,10 hr Case Study, Labile Hypertensive, 35 yr ♂ 151 Simultaneous, Same Arm BPs

	SBP*** (mm Hg)	△	DBP** (mm Hg)	△	HR** (bpm)	△
A1	134.3 ± 10.8		86.9 ± 8.8		69.2 ± 7.2	✓
		2.7 ± 4.3		1.7 ± 6.6		-0.6 ± 2.7
A2	131.6 ± 11.1		85.2 ± 8.8		69.8 ± 7.3	

**P < 0.01, ***P < 0.001

NB: A1 & A2 accounted for 85% of SBP variance (R = 0.92) but only 52% of DBP variance (R = 0.72)

Lab

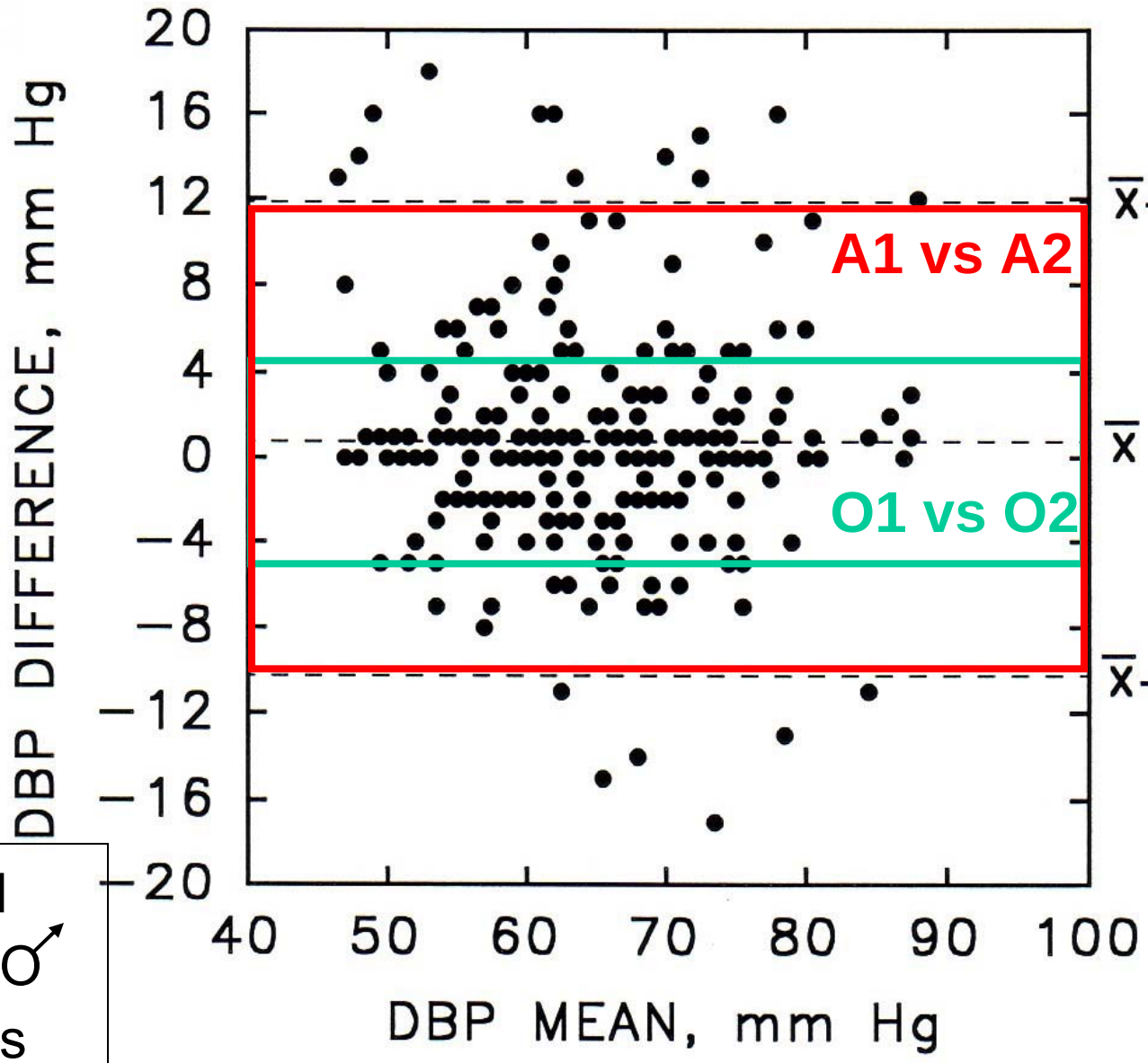


✓

15 NTN
8 ♀ , 7 ♂
243 BPs

ACCUTRACKER 1 vs ACCUTRACKER 2
DIASTOLIC BLOOD PRESSURE (DBP)

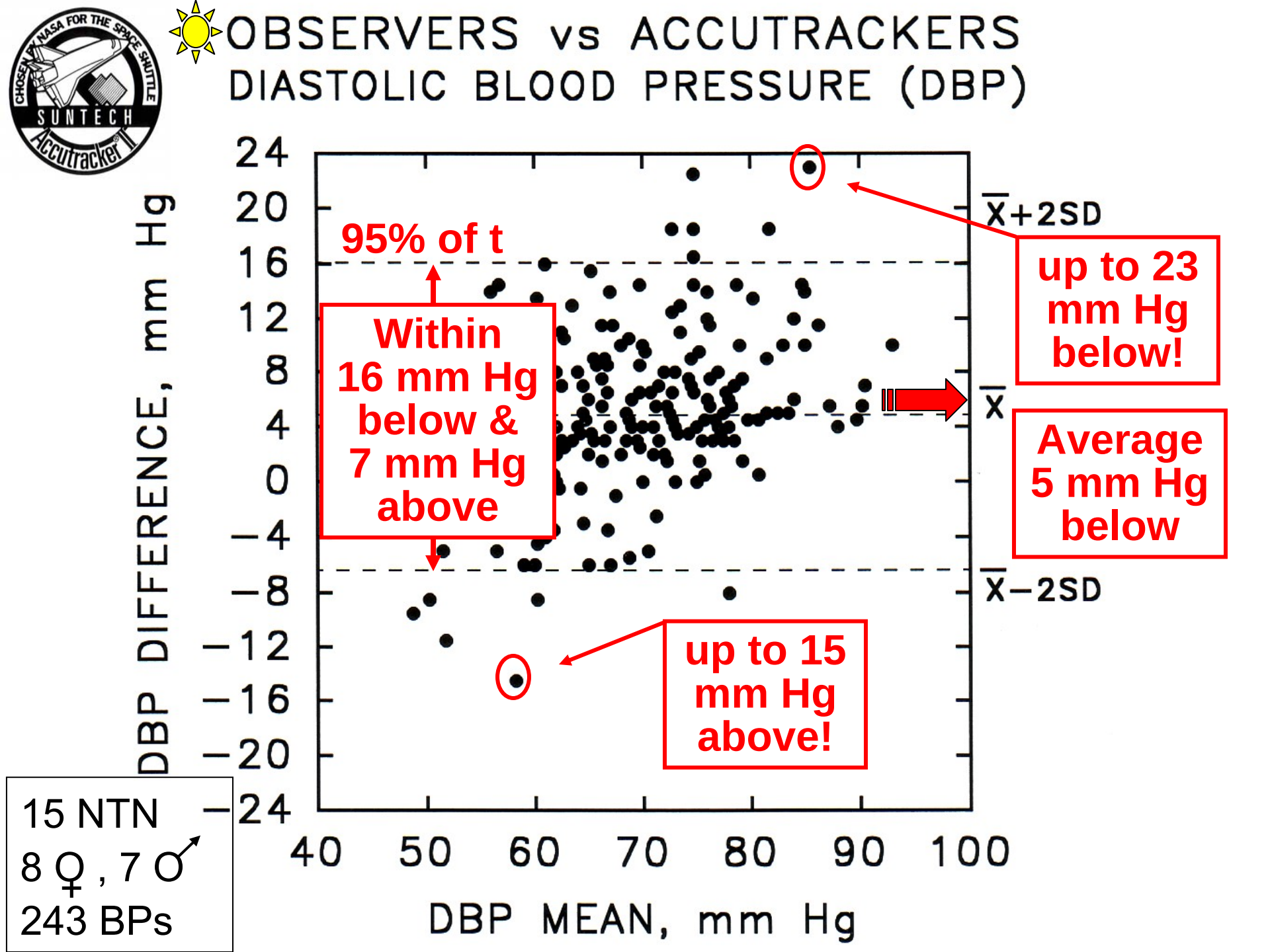
$R^2 = 0.69$



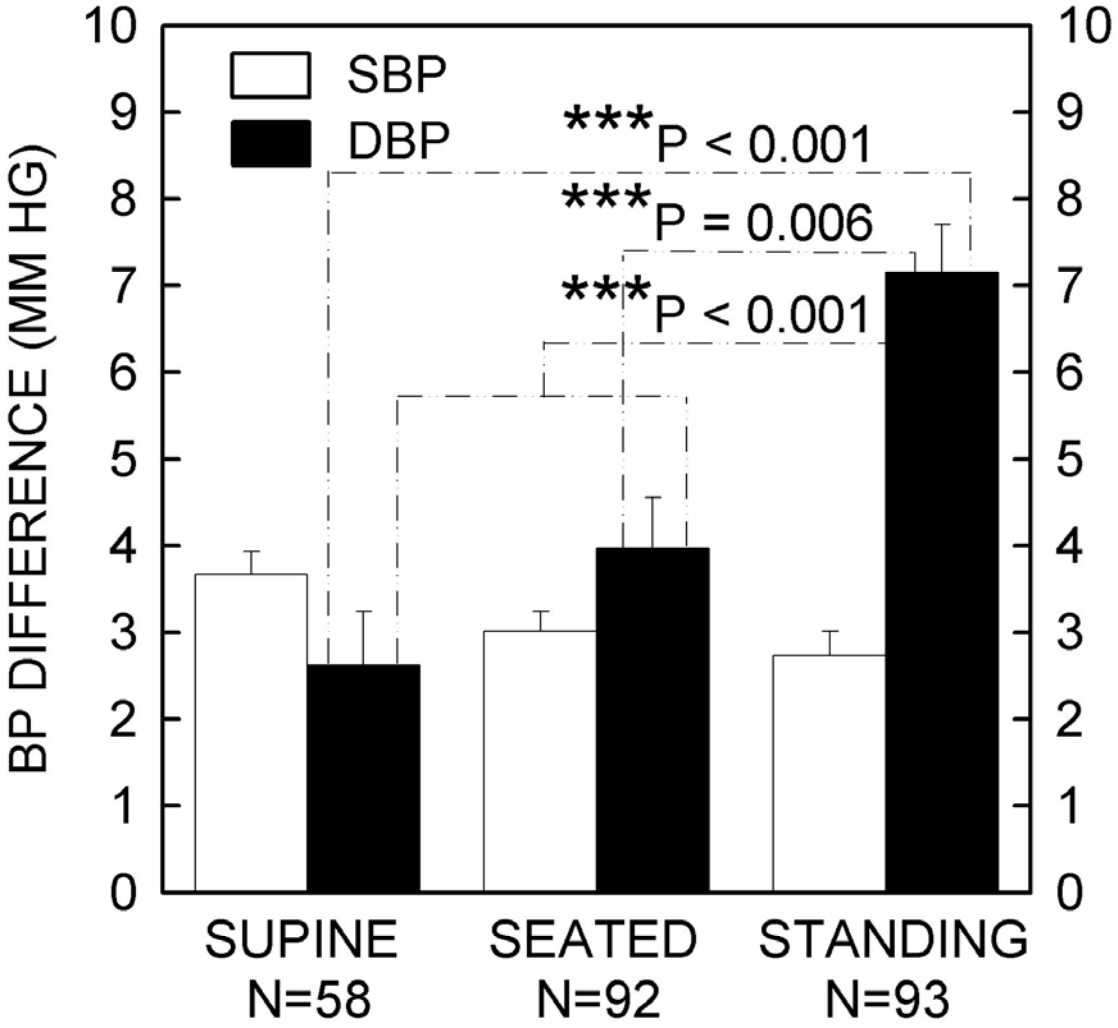
95% of t

± 10-12 mm Hg

15 NTN
8 ♀ , 7 ♂
243 BPs


OBSERVERS vs ACCUTRACKERS
DIASTOLIC BLOOD PRESSURE (DBP)
DBP DIFFERENCE, mm Hg
24
20
16
12
8
4
0
−4
−8
−12
−16
−20
−24
40
50
60
70
80
90
100
DBP MEAN, mm Hg
X̄+2SD
X̄
X̄−2SD
95% of t
Within 16 mm Hg below & 7 mm Hg above
up to 23 mm Hg below!
Average 5 mm Hg below
up to 15 mm Hg above!
15 NTN
8 ♀ , 7 ♂
243 BPs

OBSERVERS vs ABPMs in NORMOTENSIVES
POSTURAL DIFFERENCES

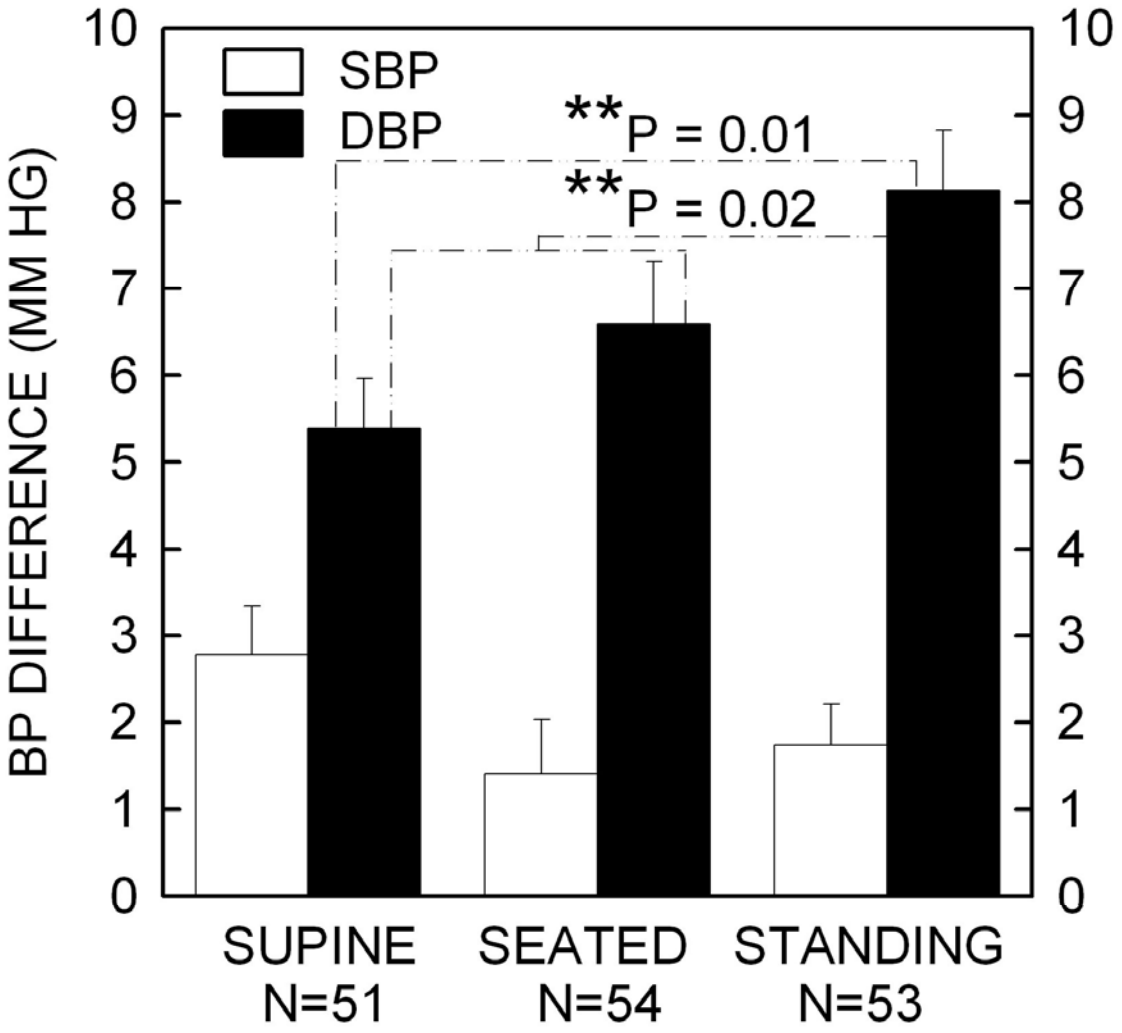


***P < 0.001, DBP Supine vs Standing

***P = 0.006, DBP Seated vs Standing

***P < 0.001, DBP Standing vs Supine & Seated

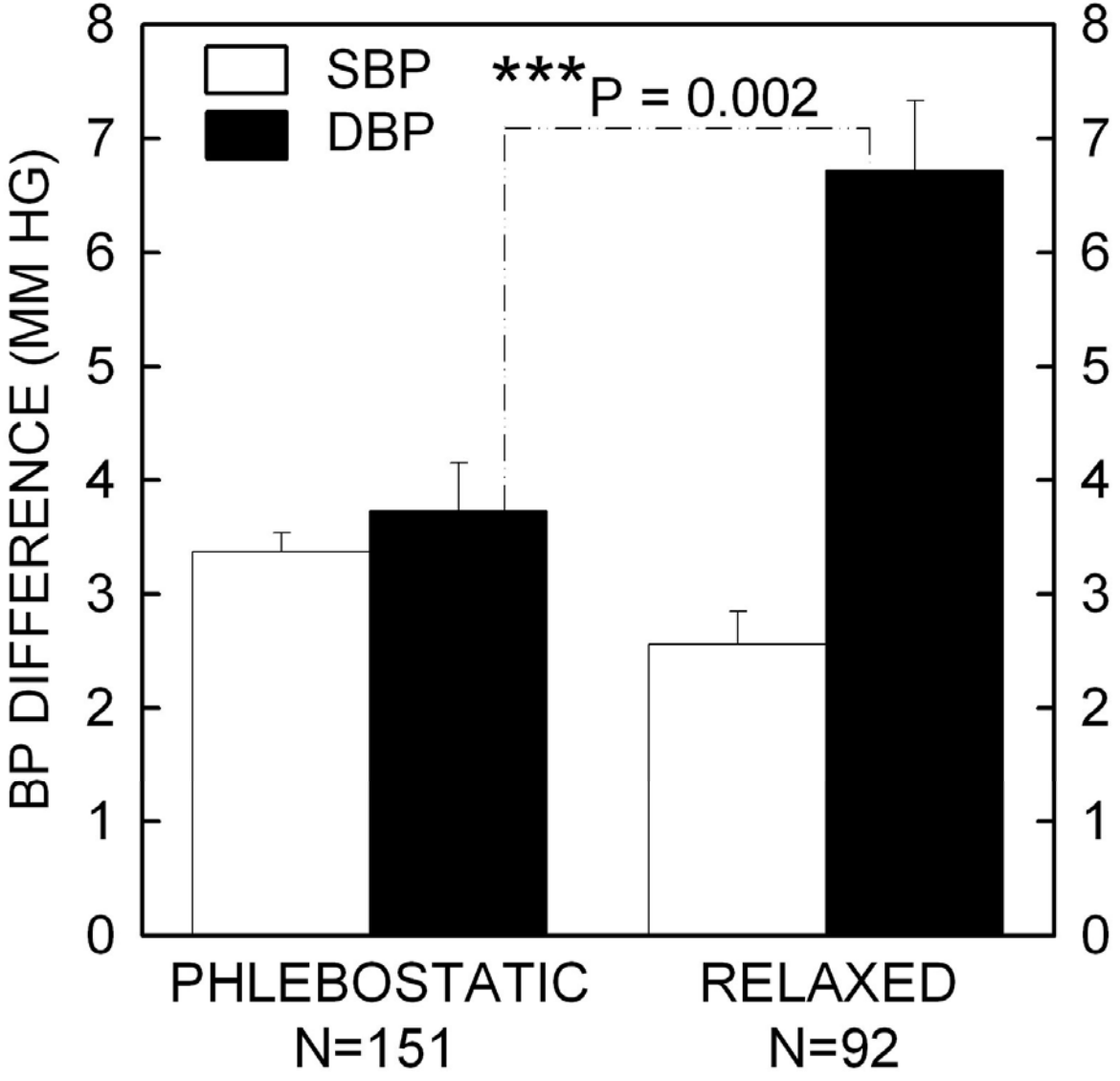
OBSERVERS vs ABPMs in 1^0 ETOH-DEPENDENTS
POSTURAL DIFFERENCES



**P = 0.01, DBP Supine vs Standing

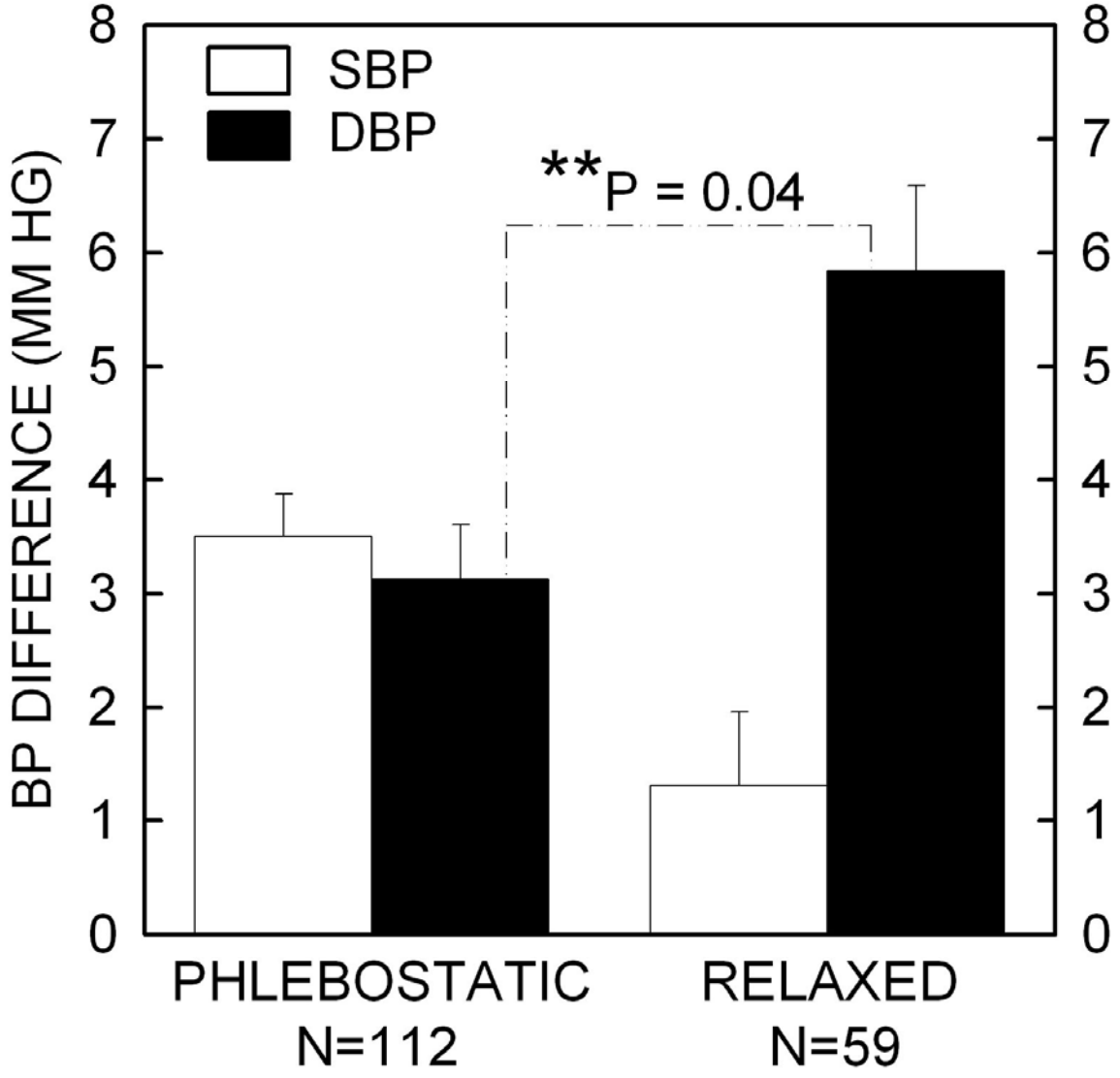
**P = 0.02, DBP Standing vs Supine & Seated

OBSERVERS vs ABPMs IN NORMOTENSIVES
ARM POSITION DIFFERENCES

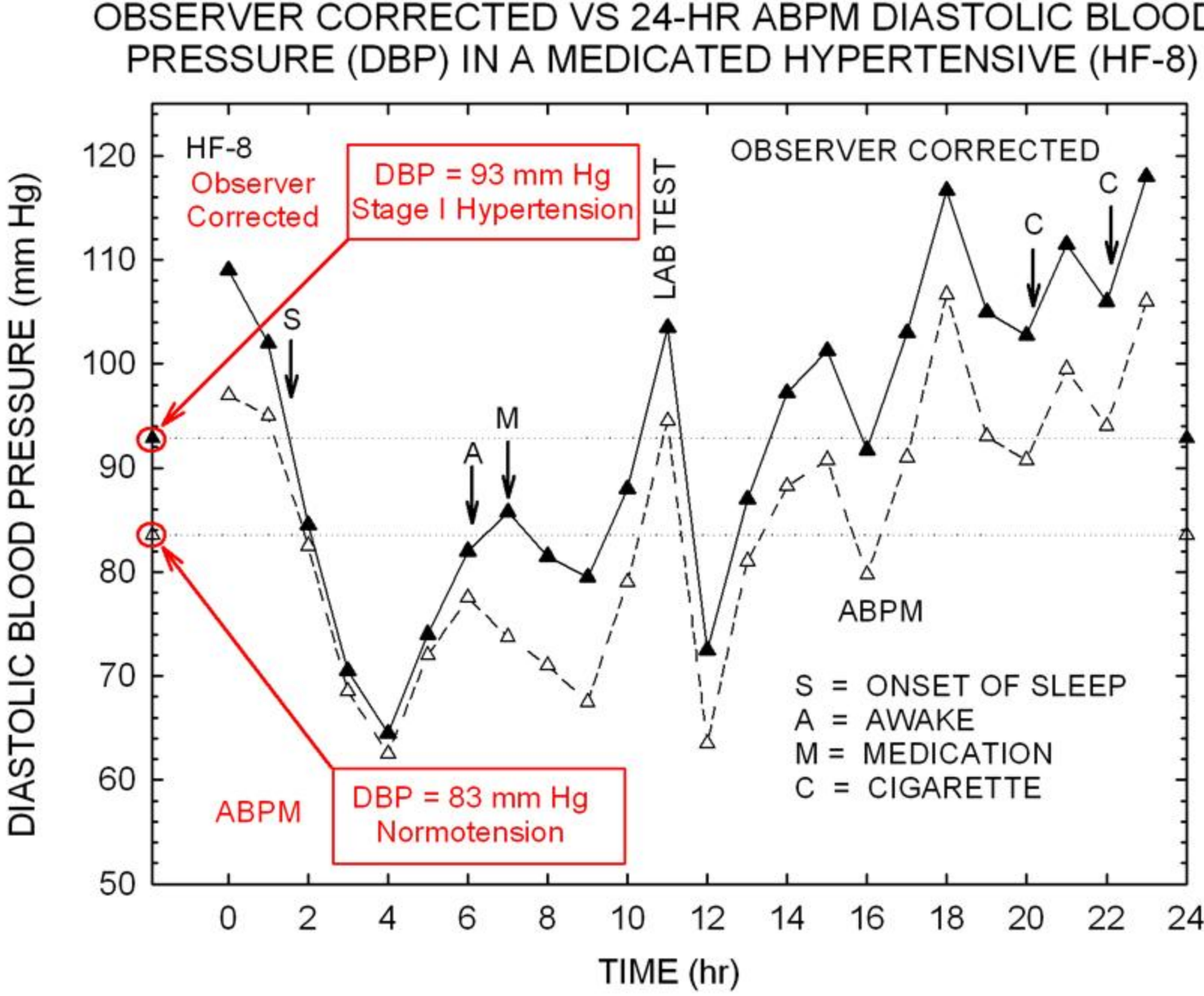


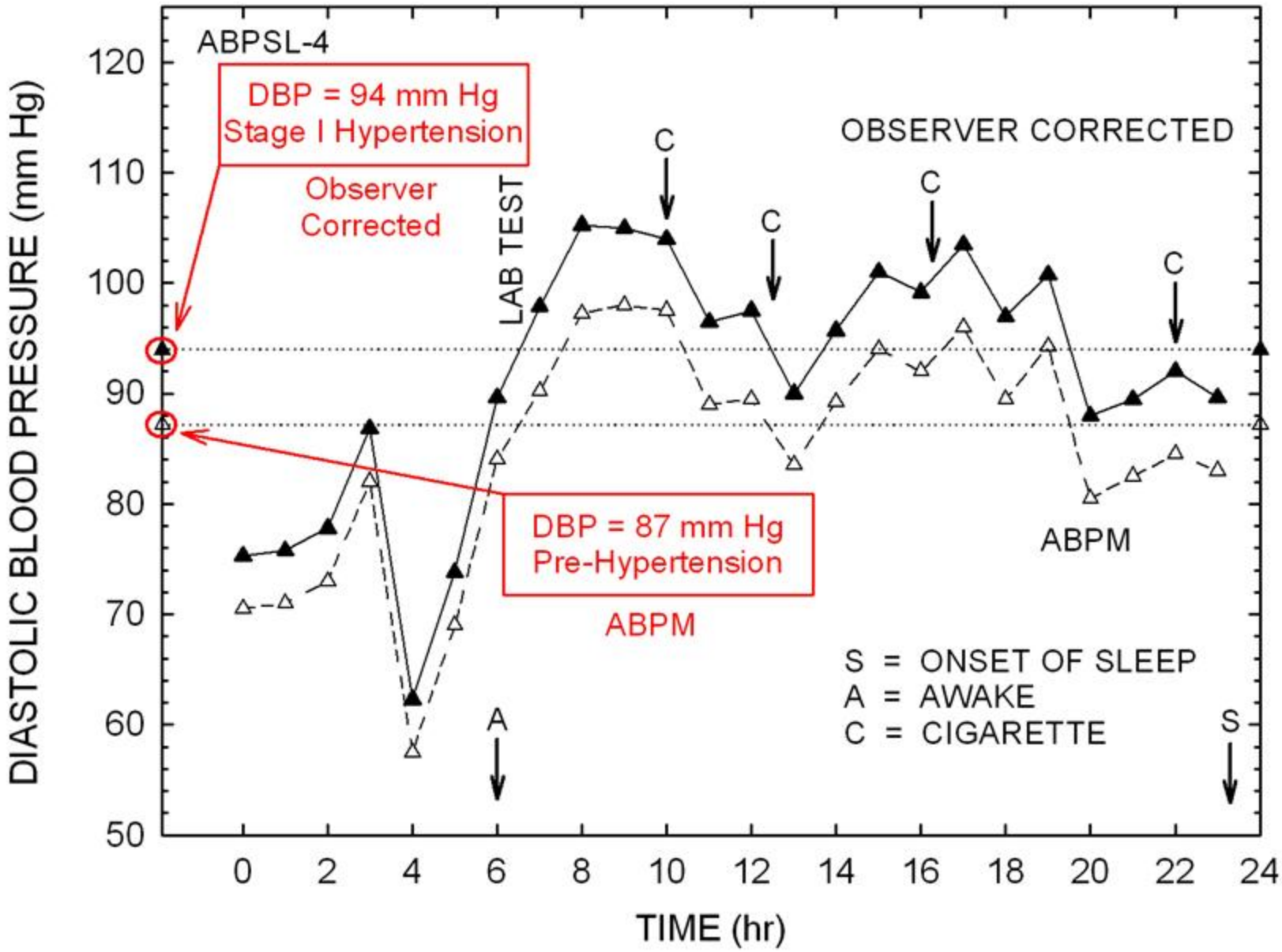
***P = 0.002, DBP Relaxed vs Phlebostatic

OBSERVERS vs ABPMs IN HYPERTENSIVES
ARM POSITION DIFFERENCES



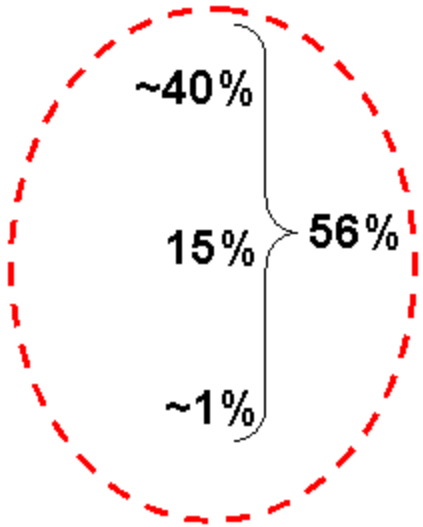
**P = 0.04, DBP Relaxed vs Phlebostatic


OBSERVER CORRECTED VS 24-HR ABPM DIASTOLIC BLOOD PRESSURE (DBP) IN A MEDICATED HYPERTENSIVE (HF-8)
DIASTOLIC BLOOD PRESSURE (mm Hg)
TIME (hr)
HF-8
Observer Corrected
OBSERVER CORRECTED
DBP = 93 mm Hg
Stage I Hypertension
LAB TEST
ABPM
DBP = 83 mm Hg
Normotension
S = ONSET OF SLEEP
A = AWAKE
M = MEDICATION
C = CIGARETTE
S
A
M
C
C
C
120
110
100
90
80
70
60
50
0
2
4
6
8
10
12
14
16
18
20
22
24


OBSERVER CORRECTED VS 24-HR ABPM DIASTOLIC BLOOD PRESSURE (DBP) IN A PRIMARY ALCOHOL DEPENDENT (ABPSL-4)
ABPSL-4
DBP = 94 mm Hg
Stage I Hypertension
Observer
Corrected
DBP = 87 mm Hg
Pre-Hypertension
ABPM
LAB TEST
OBSERVER CORRECTED
ABPM
S = ONSET OF SLEEP
A = AWAKE
C = CIGARETTE
DIASTOLIC BLOOD PRESSURE (mm Hg)
TIME (hr)
120
110
100
90
80
70
60
50
0
2
4
6
8
10
12
14
16
18
20
22
24

CLINICALLY SIGNIFICANT DIFFERENCES IN ABPM & OBSERVER-CORRECTED NHLBI (1997, 2003) CLASSIFICATIONS OF 1275 ABPM FIELD SYSTOLIC (SBP) & DIASTOLIC (DBP) PRESSURES IN 11 PRIMARY ALCOHOL-DEPENDENTS

ABPM vs Observer NHLBI Classification	%SBP Values	%DBP Values
+1 *ABPM 1 Category Above Observers* (eg ABPM indicates Prehypertension, Observers Normotension)	3%	1%
+0 *ABPM Identical Category as Observers* (eg Both ABPM & Observers indicate Normotension)	85%	44%
-1 *ABPM 1 Category Below Observers* (eg ABPM indicates Normotension, Observers Prehypertension)	12%	~40%
-2 *ABPM 2 Categories Below Observers* (eg ABPM indicates Normotension, Observers STAGE I Hypertension)	0%	15%
-3 *ABPM 3 Categories Below Observers* (eg ABPM indicates Normotension, Observers STAGE II Hypertension)	0%	~1%



CLINICALLY SIGNIFICANT DIFFERENCES IN ABPM & OBSERVER-CORRECTED NHLBI (1997, 2003) CLASSIFICATIONS OF LABORATORY SYSTOLIC (SBP) & DIASTOLIC (DBP) PRESSURES IN 11 PRIMARY ALCOHOL-DEPENDENTS

Patient	BP Source	SBP	NHLBI Class		DBP	NHLBI Class	
1 ♂ 37 yr	Observers	129.7	Normal	✔	87.5	Pre HTN	⊘
	ABPM	127.7	Normal		80.8	Normal	
	Δ	2.0			6.7		
2 ♂ 37 yr	Observers	128.4	Normal	✔	89.1	Pre HTN	⊘
	ABPM	124.5	Normal		80.6	Normal	
	Δ	3.9			8.5		
3 ♂ 49 yr	Observers	155.7	Stage I HTN	✔	92.9	Stage I HTN	⊘
	ABPM	151.2	Stage I HTN		88.4	Pre HTN	
	Δ	4.5			4.5		
4 ♂ 32 yr	Observers	121.8	Normal	✔	86.6	Pre HTN	⊘
	ABPM	120.2	Normal		79.9	Opt Normal	
	Δ	1.6			6.7		
5 ♀ 29 yr	Observers	104.5	Optimal BP	✔	80.3	Normal	⊘
	ABPM	103.8	Optimal BP		71.2	Optimal BP	
	Δ	0.7			9.1		

6 ♂ 31 yr	Observers	119.3	Optimal BP	✔	87.6	Pre HTN	⊘
	ABPM	117.9	Optimal BP		79.9	Optimal BP	
	Δ	1.4			7.7		
7 ♂ 39 yr	Observers	138.7	Pre HTN	✔	91.0	Stage I HTN	⊘
	ABPM	138.2	Pre HTN		84.7	Normal	
	Δ	0.5			6.3		
8 ♀ 35 yr	Observers	114.3	Optimal BP	✔	80.4	Normal	⊘
	ABPM	110.0	Optimal BP		68.4	Optimal BP	
	Δ	4.3			12.0		
9 ♂ 30 yr	Observers	112.5	Optimal BP	✔	81.9	Normal	⊘
	ABPM	109.8	Optimal BP		73.5	Optimal BP	
	Δ	2.7			8.4		
10 ♂ 43 yr	Observers	120.8	Normal	✔	92.6	Stage I HTN	⊘
	ABPM	120.4	Normal		86.4	Pre HTN	
	Δ	0.4			6.1		
11 ♂ 59 yr	Observers	165.1	Stage II HTN	✔	98.8	Stage I HTN	✔
	ABPM	165.1	Stage II HTN		97.1	Stage I HTN	
	Δ	0.0			1.7		

SUMMARY & CONCLUSIONS

1. An approved ABPM significantly underestimates DBP. Two identical model ABPMs have a lower level of agreement than two clinicians using a Hg column.

2. The magnitude of ABPM underestimation is statistically & clinically significant & varies according to posture.

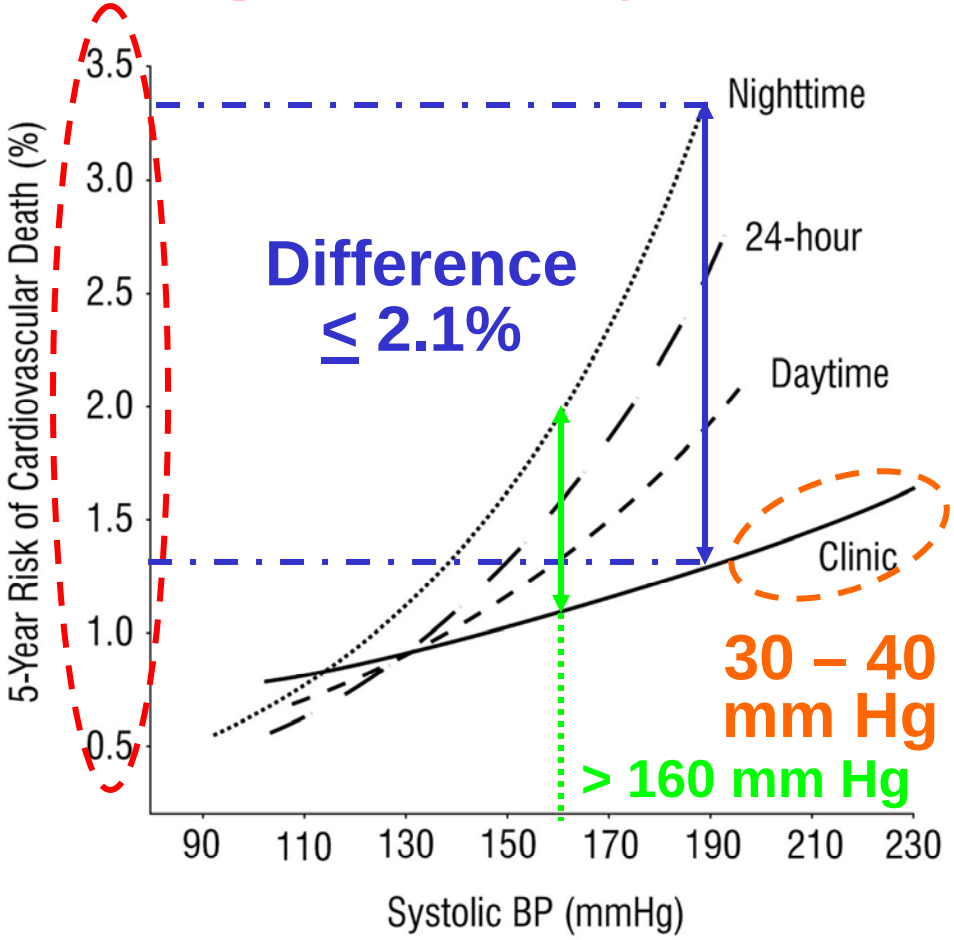
3. Diastolic pressure underestimations are greatest when subjects are awake & standing with the arm relaxed.

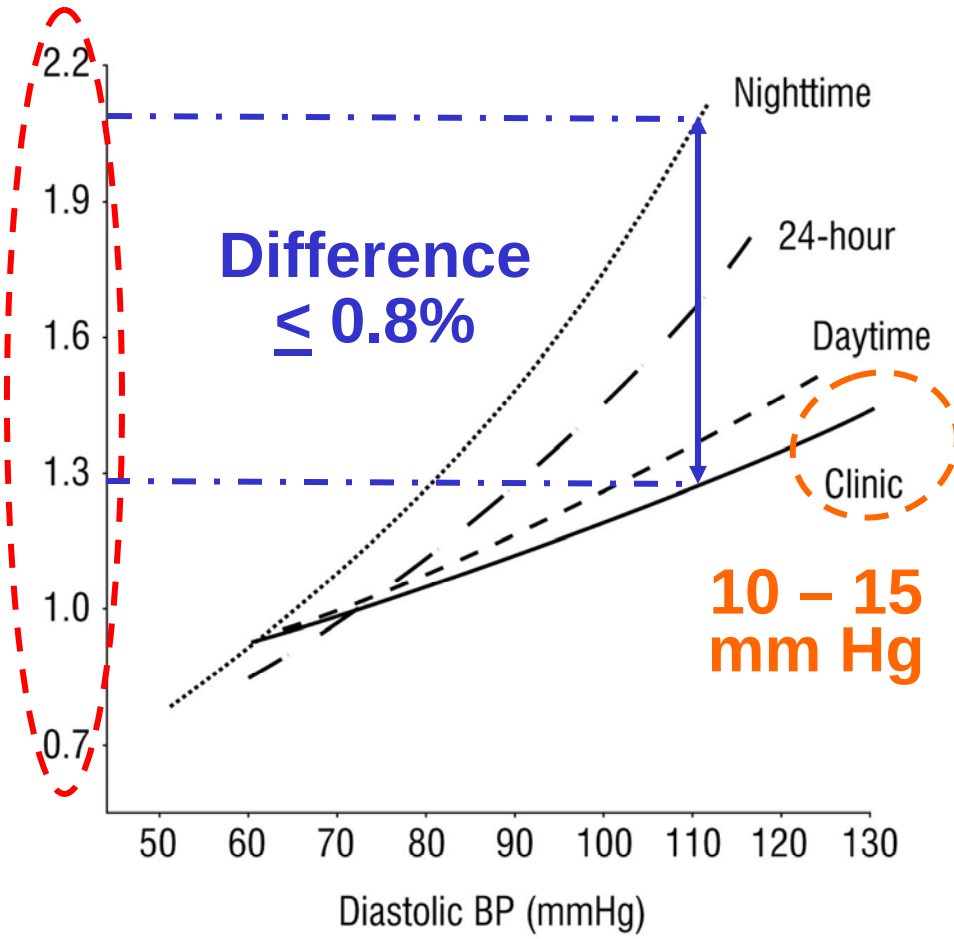
4. Variable underestimations may lead to misdiagnosis & mismanagement of patients & to errors in interpreting research results.

5. International (ESH, BHS) & US National (AAMI) approval protocols should be revised to require testing for a variety of postures. Without more comprehensive, postural & activity testing, ABPMs cannot be claimed as approved for truly ambulatory conditions.

DISCUSSION

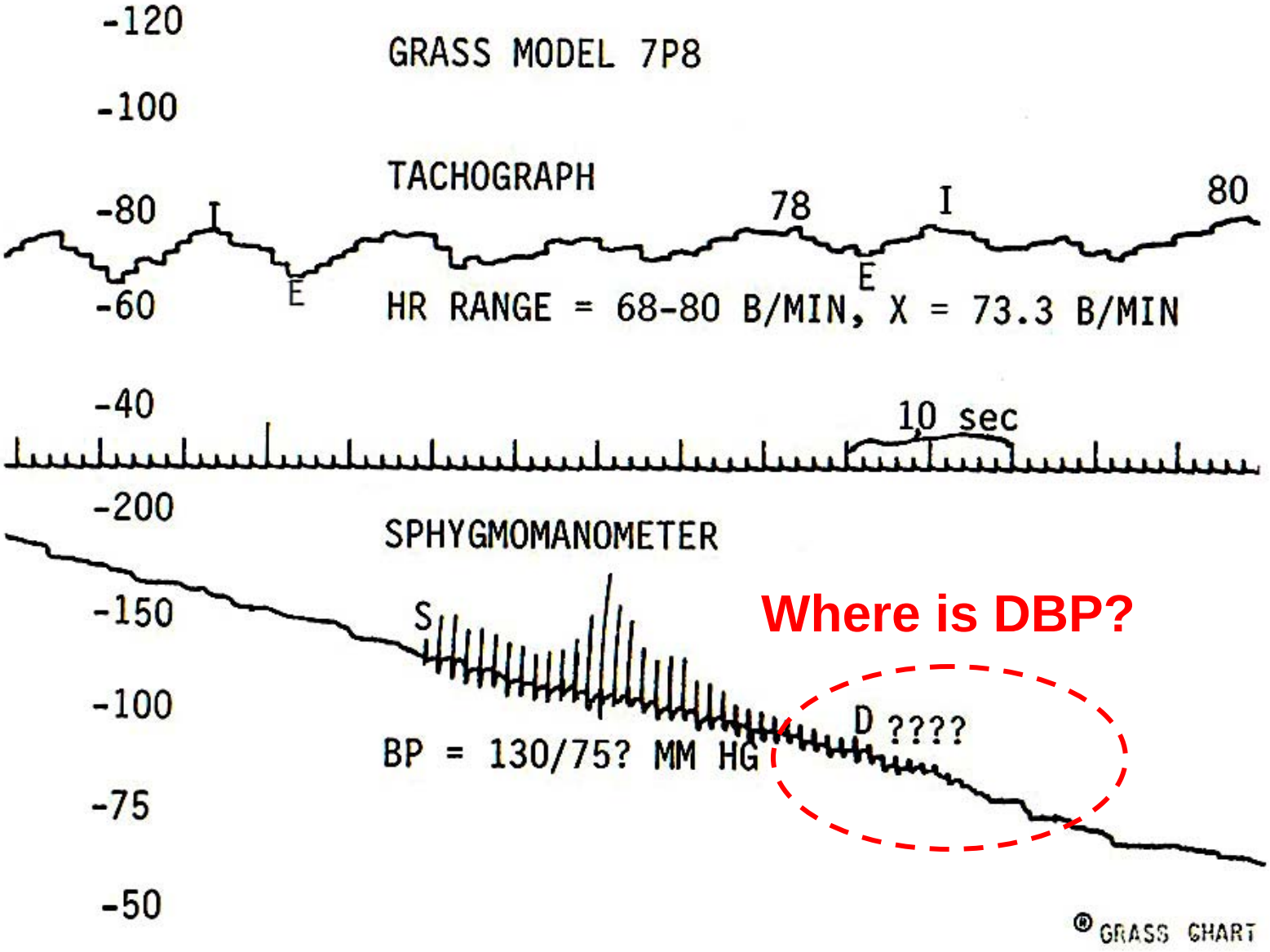
Are ABPMs truly superior to Clinic BPs in predicting cardiovascular mortality?



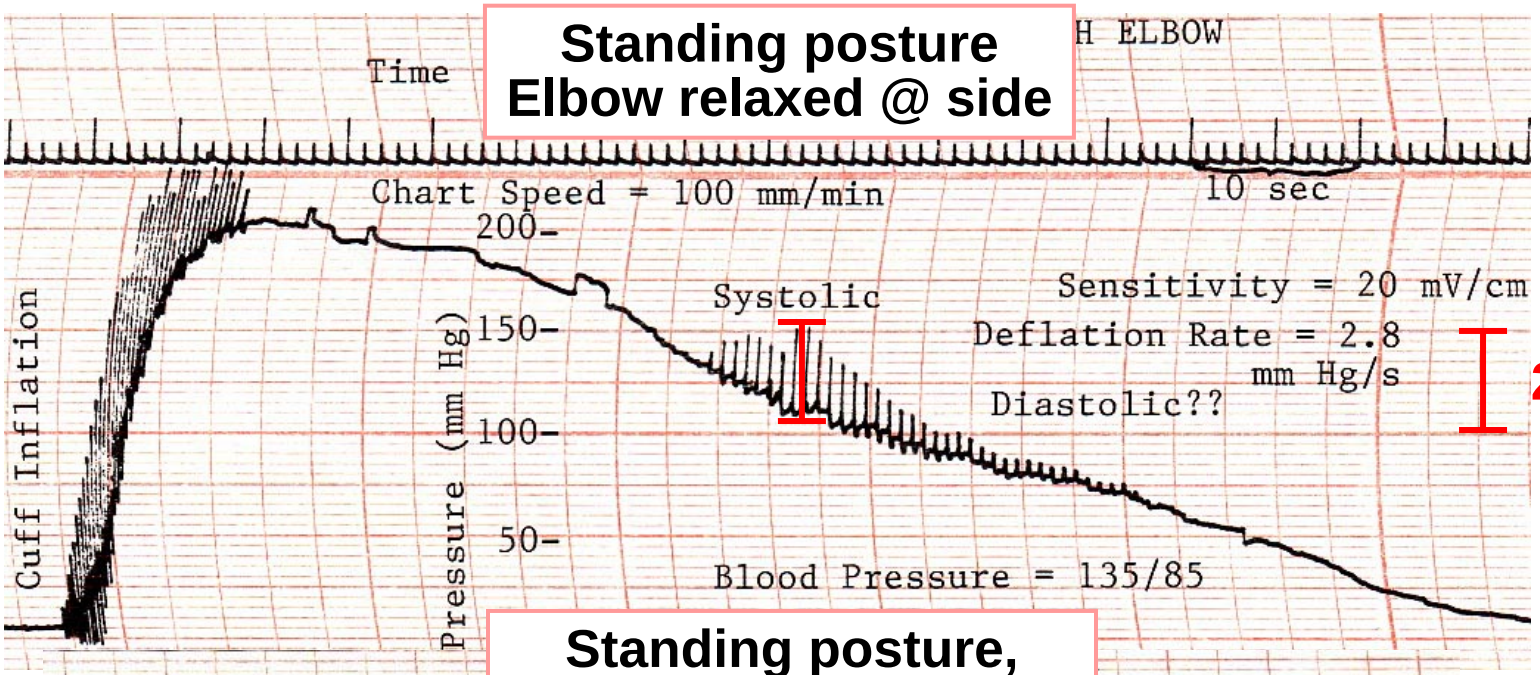


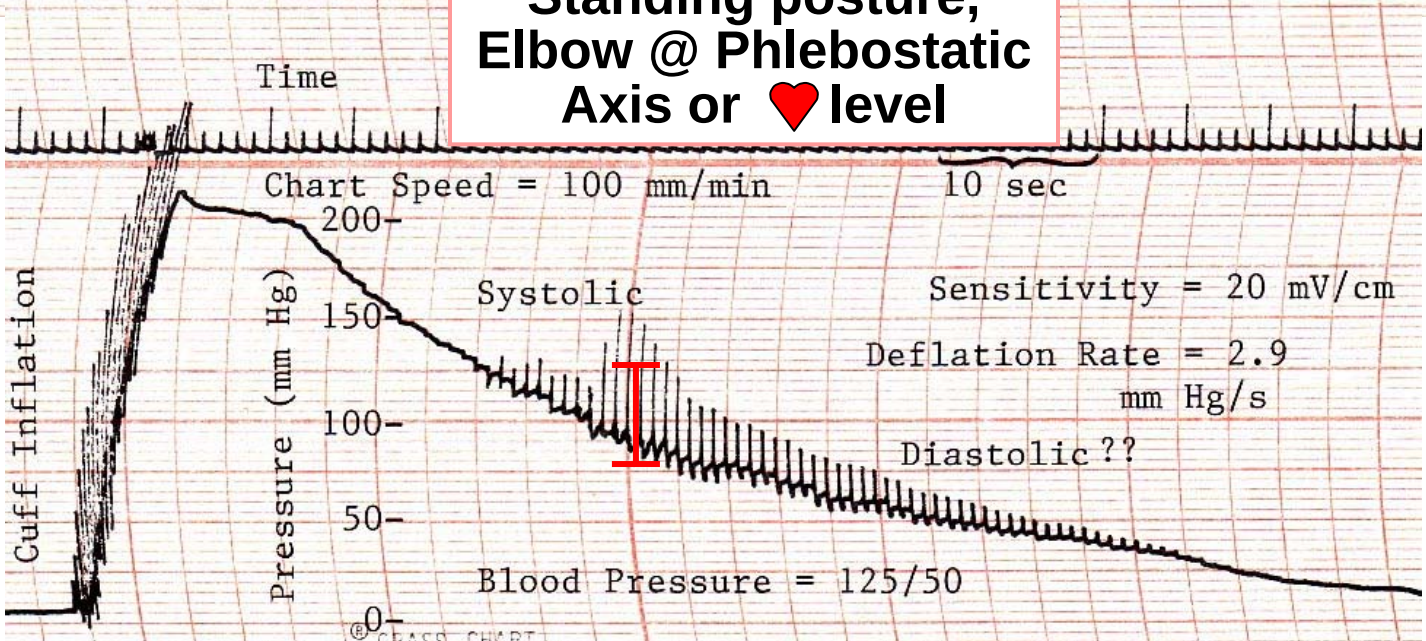
Source: E. Dolan, A. Stanton, L. Thijs, K. Hinedi, N. Atkins, S. McClory, E.D. Hond, P. McCormack, J.A. Staessen, E. O'Brien. *Hypertension*. 2005; 46:156-161.

Difficulty in Determining Diastolic Endpoint

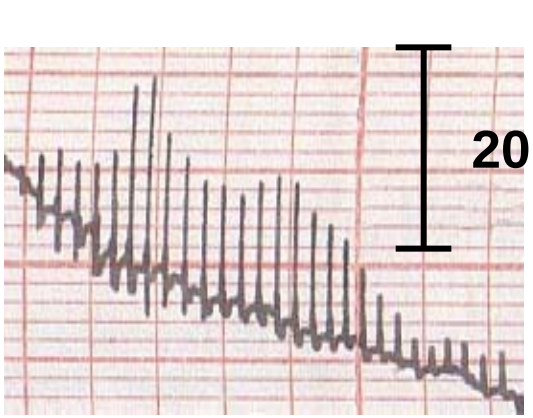


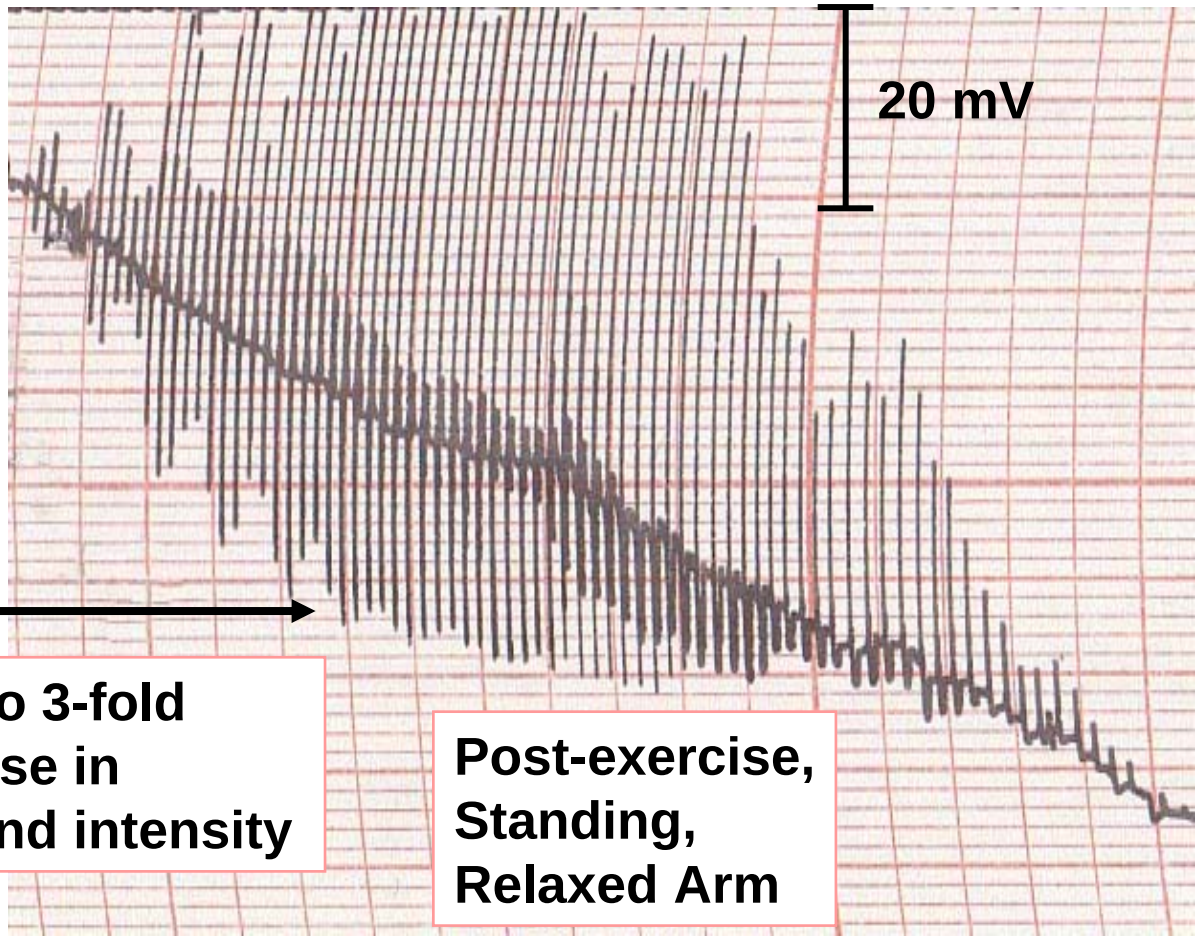
K-Sound Intensity Changes w/Body & Arm Position





K-Sound Intensity Changes with Activity





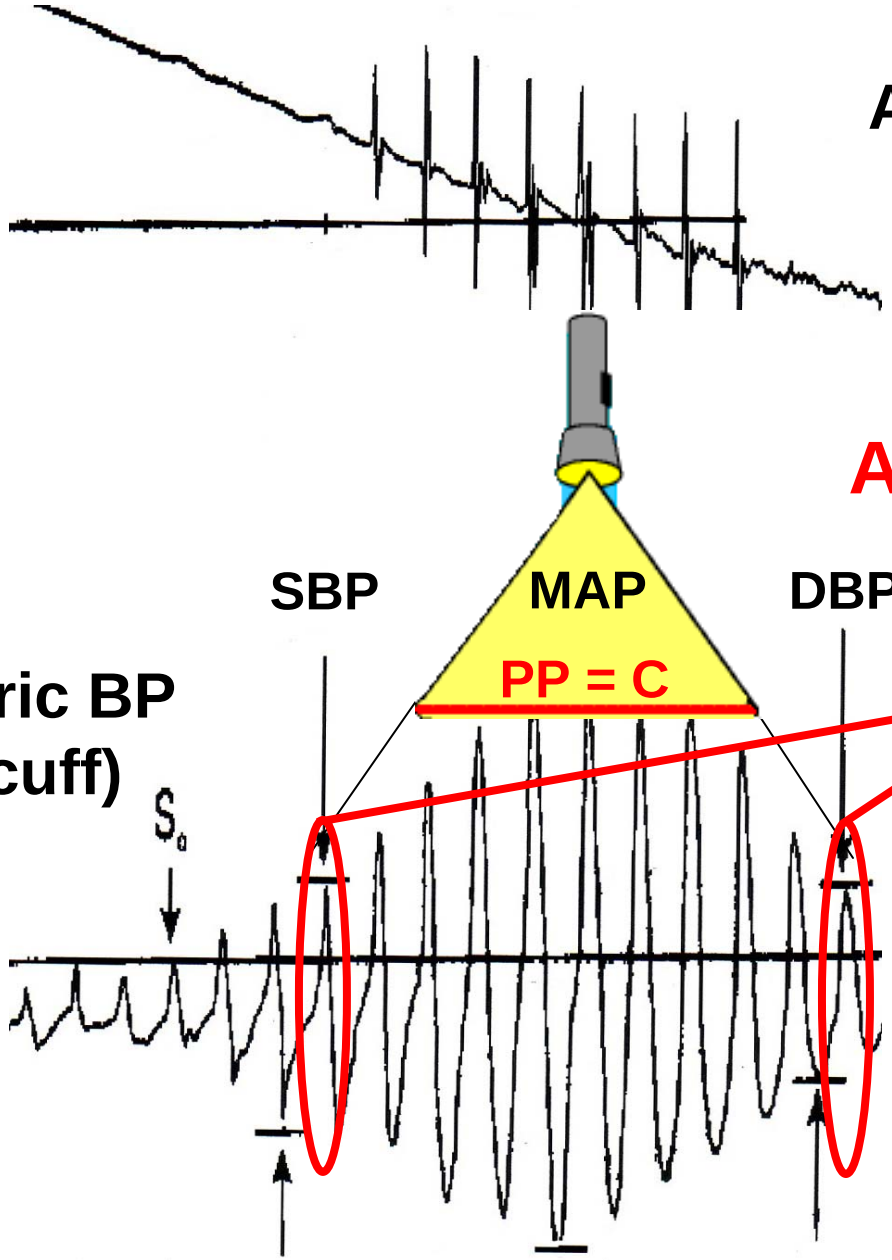
Pre-exercise, Standing, Relaxed Arm

≥ 2.5 to 3-fold increase in K-sound intensity

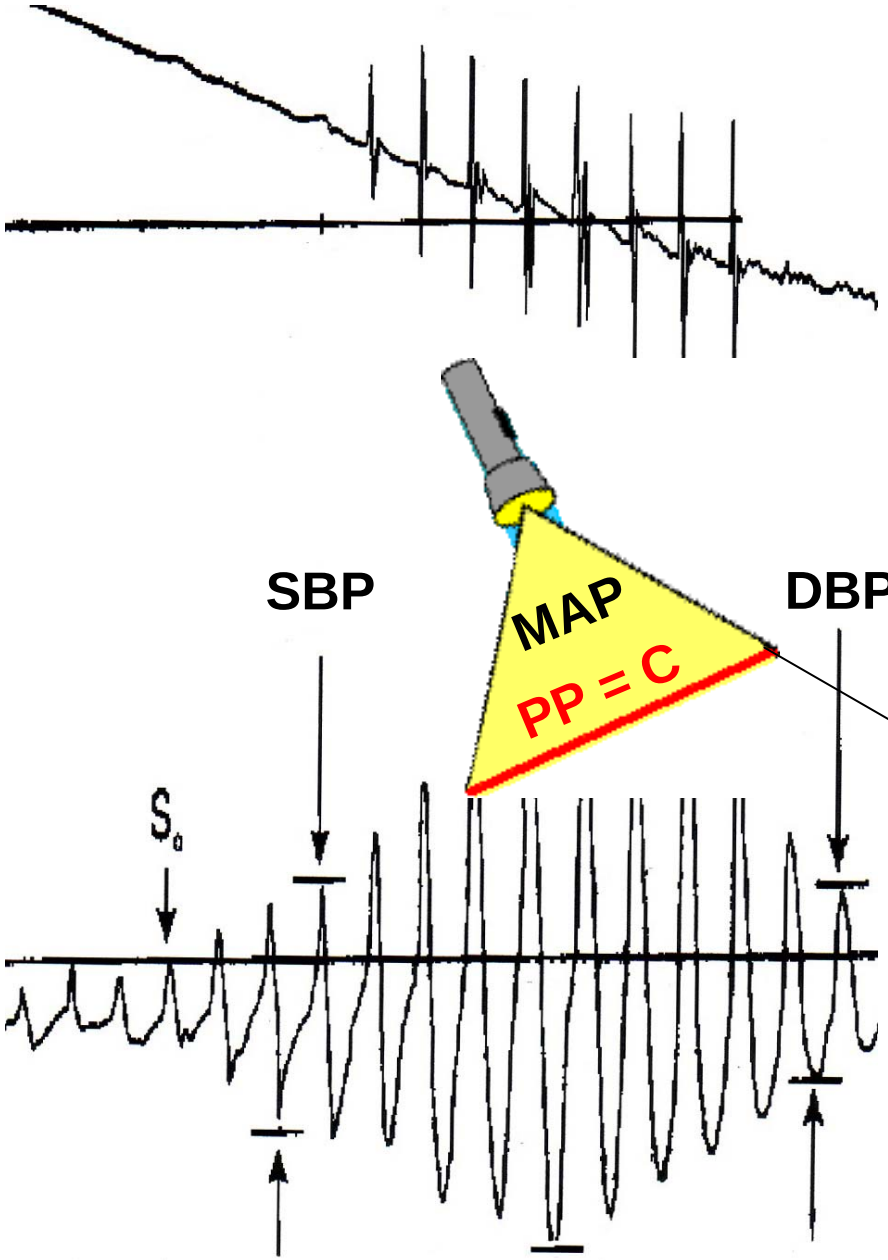
Post-exercise, Standing, Relaxed Arm

15 squat repetitions

Oscillometry Flashlight-Nomogram Effect

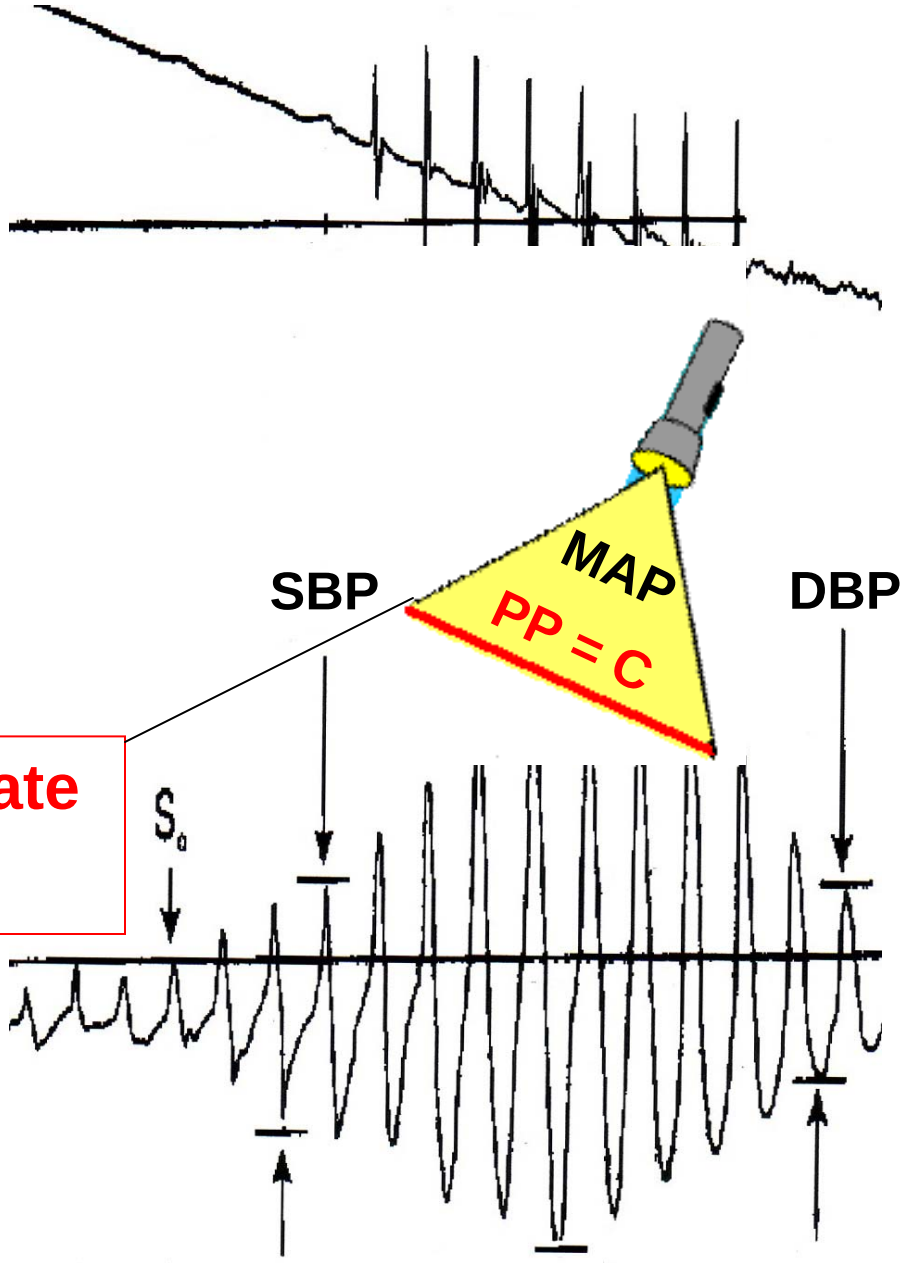


Oscillometry Flashlight Effect



Underestimate DBP

Oscillometry Flashlight Effect



Overestimate SBP

1. Use Dual Monitor Protocol with postural challenges to verify accuracy & reliability

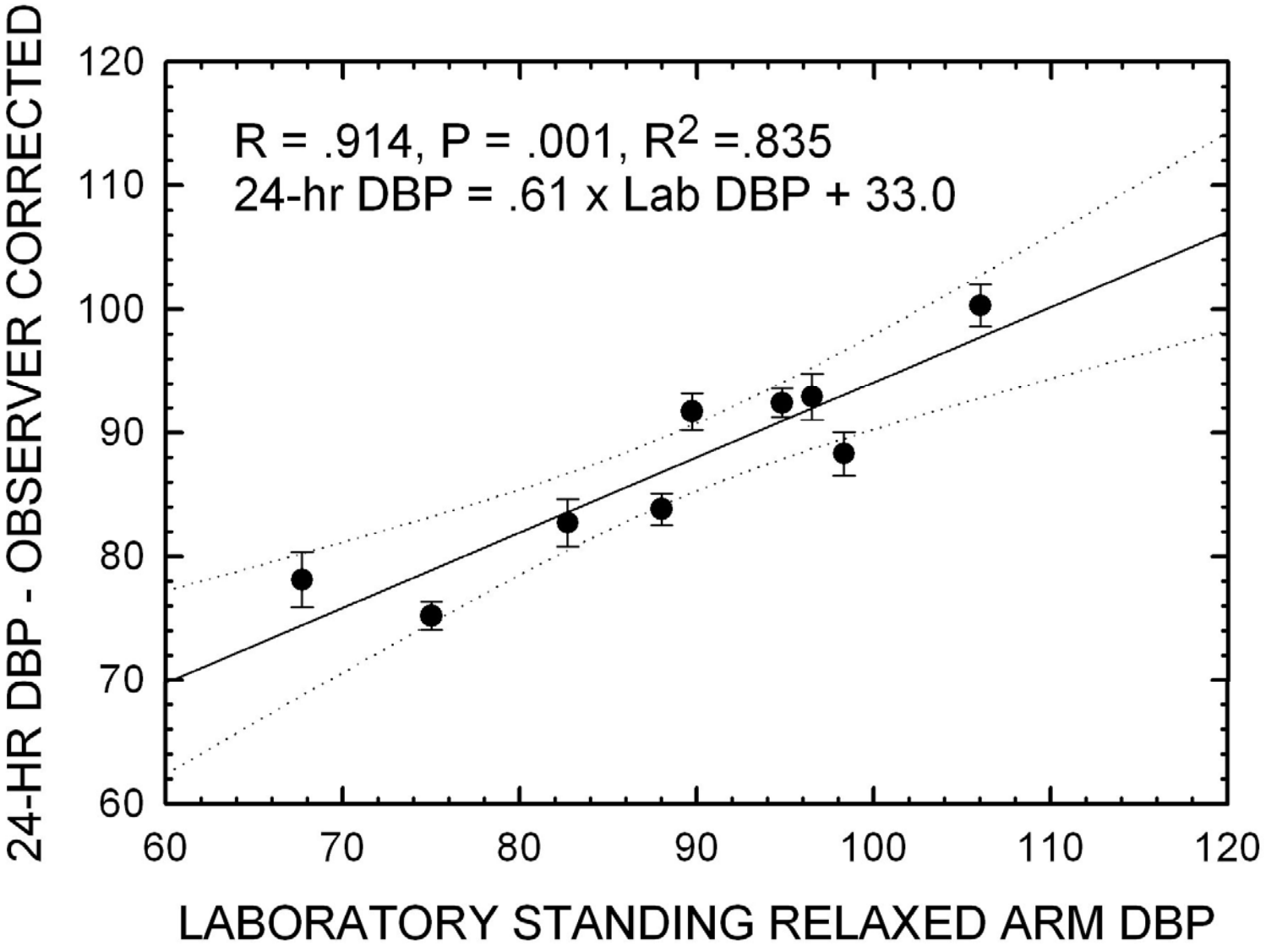
2. Use Correction Factors for 24-hr ABPM values

3. Develop postural & activity adjusting ABPMs

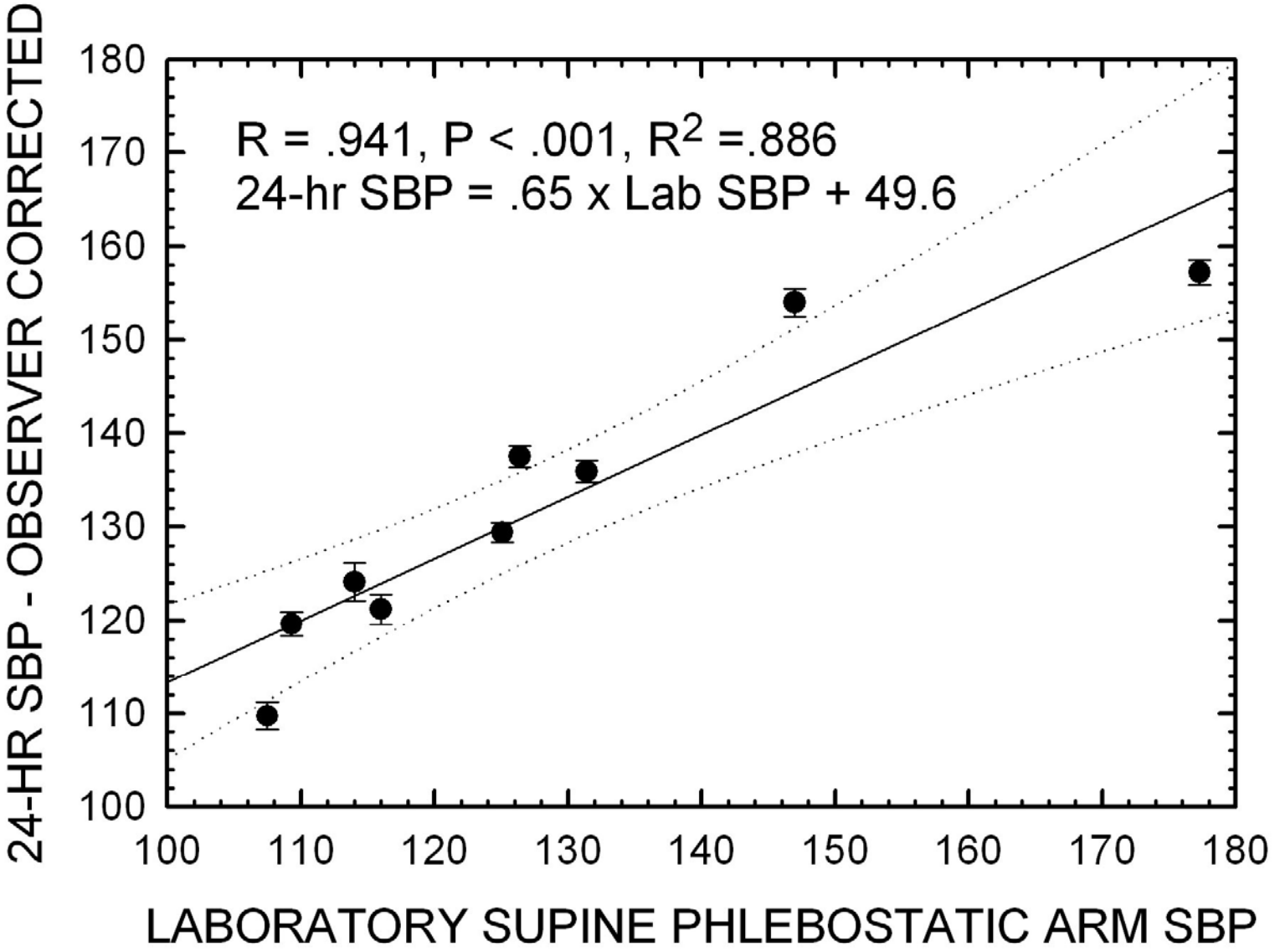
4. Modify AAMI, BHS, & ESH/IP criteria to require postural & activity challenges

5. Reflect back & return to basic physiology

AVERAGE 24-HR DIASTOLIC BLOOD PRESSURE (DBP) vs. LABORATORY STANDING RELAXED ARM DBP IN SUSPECTED HYPERTENSIVES



AVERAGE 24-HR SYSTOLIC BLOOD PRESSURE (SBP) vs. LABORATORY SUPINE PHLEBOSTATIC ARM SBP IN PRIMARY ALCOHOL DEPENDENTS (1^0 ETOH)



Comparing Posture & Arm Position for Lab Measurements with 24-hr, Awake & Sleep Systolic (SBP) and Diastolic (DBP) Blood Pressures Obtained by Ambulatory Blood Pressure Monitoring (ABPM) In Medicated & Non-Medicated Hypertensives

	SBP from ABPM						DBP from ABPM					
	24-hr		Awake		Sleep		24-hr		Awake		Sleep	
Lab Position	R	R^2	R	R^2	R	R^2	R	R^2	R	R^2	R	R^2
Supine	.671*	.450	.516	.266	.555	.308	.762*	.581	.652	.425	.694*	.481
Phlebostatic	P=.048		P=.155 NS		P=.121 NS		P=.017		P=.057 NS		P=.038	
Seated	.680*	.462	.426	.181	.625	.391	.695*	.483	.542	.294	.681*	.464
Phlebostatic	P=.044		P=.253 NS		P=.072 NS		P=.038		P=.132 NS		P=.043	
Seated ✓	.752*	.566	.578	.334	.520	.270	.667*	.445	.760*	.578	.403	.162
Relaxed	P=.019		P=.103 NS		P=.151 NS		P=.050		P=.017		P=.282 NS	
Standing	.327	.107	.174	.030	.400	.160	.800*	.640	.724*	.524	.734*	.539
Phlebostatic	P=.390 NS		P=.655 NS		P=.286 NS		P=.010		P=.027		P=.024	
Standing ✓	.489	.239	.257	.066	.582	.339	.914*	.835	.828*	.686	.761*	.579
Relaxed	P=.181 NS		P=.505 NS		P=.100 NS		P=.001		P=.006		P=.017	
Overall	.581	.338	.584	.341	.418	.175	.866*	.750	.768*	.590	.762*	.581
	P=.101 NS		P=.099 NS		P=.263 NS		P=.003		P=.016		P=.017	

Best Lab/Clinic Postures, Arm Positions & Equations for Predicting ABPM 24-hr, Awake & Sleep Blood Pressures in Primary Alcohol-Dependents (1^0 ETOH) & Hypertensives (HTN)

Group	Pressure	24-hr	Awake	Sleep
1^0 ETOH	SBP	Supine Phlebostatic R=.941, P<.001, R^2=.886 *24-hrBP=.65LabBP+49.6*	Seated Relaxed* R=.921, P<.001, R^2=.848 *AwakeBP=.85LabBP+30.1*	Supine Phlebostatic R=.864, P=.001, R^2=.746 *SleepBP=.79LabBP+12.7*
	DBP	Supine Phlebostatic R=.732, P=.010, R^2=.536 *24-hrBP=.49LabBP+45.5*	Supine Phlebostatic R=.670, P=.024, R^2=.449 *AwakeBP=.39LabBP+57.1*	Supine Phlebostatic R=.672, P=.023, R^2=.452 *SleepBP=.94LabBP-7.5*
HTN	SBP	Seated Relaxed R=.752, P=.019, R^2=.566 *24-hrBP=.47LabBP+73.9*	NS	NS
	DBP	Standing Relaxed R=.914, P=.001, R^2=.835 *24-hrBP=.61LabBP+33.0*	Standing Relaxed R=.828, P=.006, R^2=.686 *AwakeBP=.50LabBP+48.7*	Standing Relaxed R=.761, P=.017, R^2=.579 *SleepBP=.51LabBP+25.3*

* NB: For 1^0ETOH, in predicting ***Awake*** ABPM, Supine Phlebostatic (R=.920, P<.001, R^2=.846; *AwakeBP=.61LabBP+58.3*) was a close second behind the Seated Relaxed position.

SpaceLabs 90207 Problems with Variability Underestimation & Special Populations

In pregnancy

In pregnancy

In pre-eclampsia**

In pre-eclampsia

In children

In elderly, supine over all pressures

During hemodialysis

NB: **SBP Underestimation 10 ± 10 mm Hg
**DBP Underestimation 8 ± 7 mm Hg

See *www.dableducational.org* for detailed references.

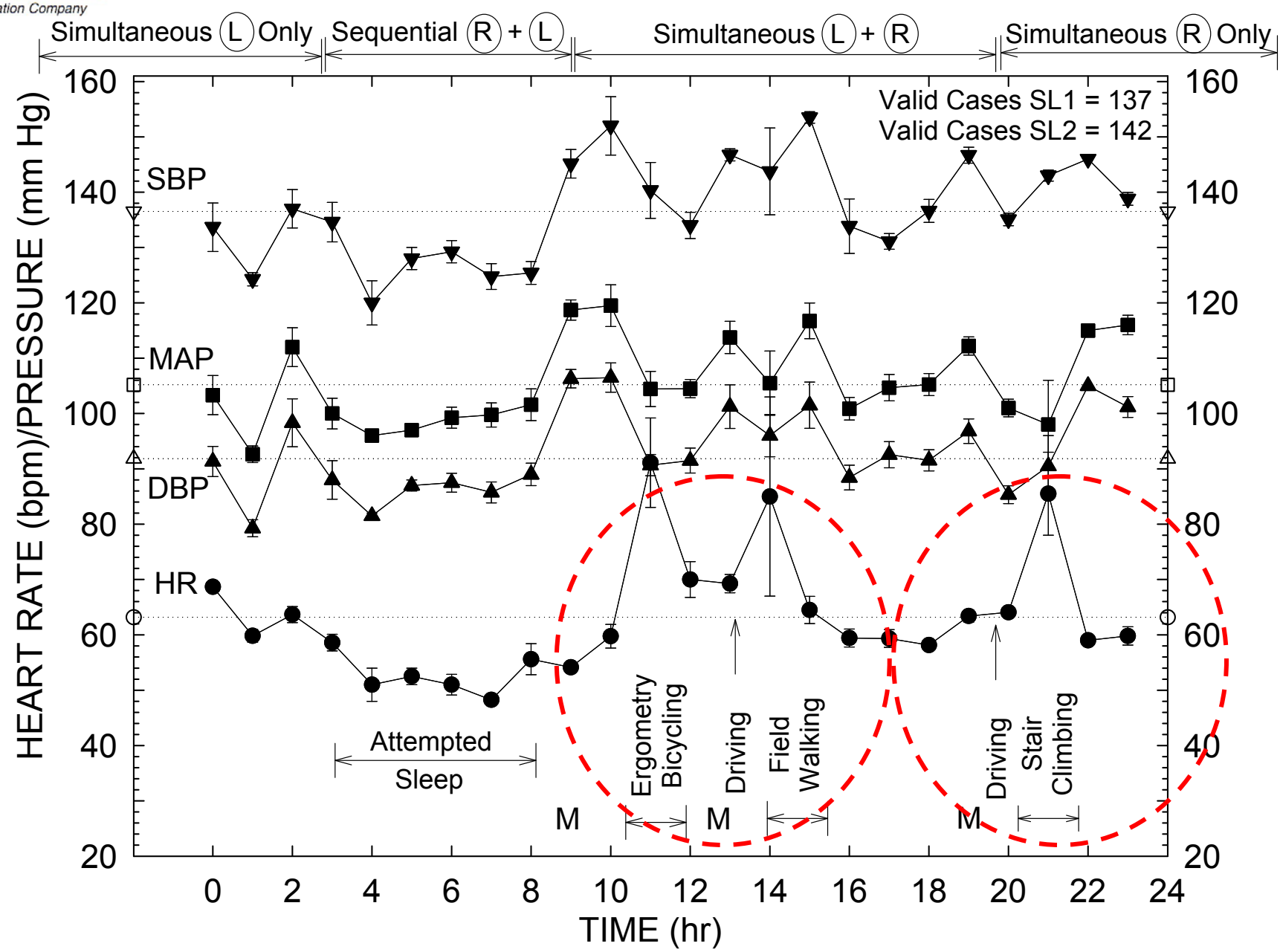
SpaceLabs 90207 BP Success (S), Error (E) & Movement Artifact (M), Dual Monitor Field Protocol

	Overall, Limited Motion		Stair Ascent/Descent Only	
	SL1	SL2	SL1 **	SL2 **
S	81%	81%	12%	29%
E	19%	19%	88%	71%
M	(14%)	(11%)	(13%)	(20%)

**NB: Both SL1 & SL2 exhibited “run-away” inflations on stair ascent, likely incorrectly perceiving motion artifact as inability to exceed SBP. Both devices largely motion & vibration intolerant.

SpaceLabs Medical
The Clinical Information Company

TWO 24-HR ABPM SPACELABS 90207 UNITS
DUAL-MONITOR FIELD PROTOCOL, LABILE HYPERTENSIVE



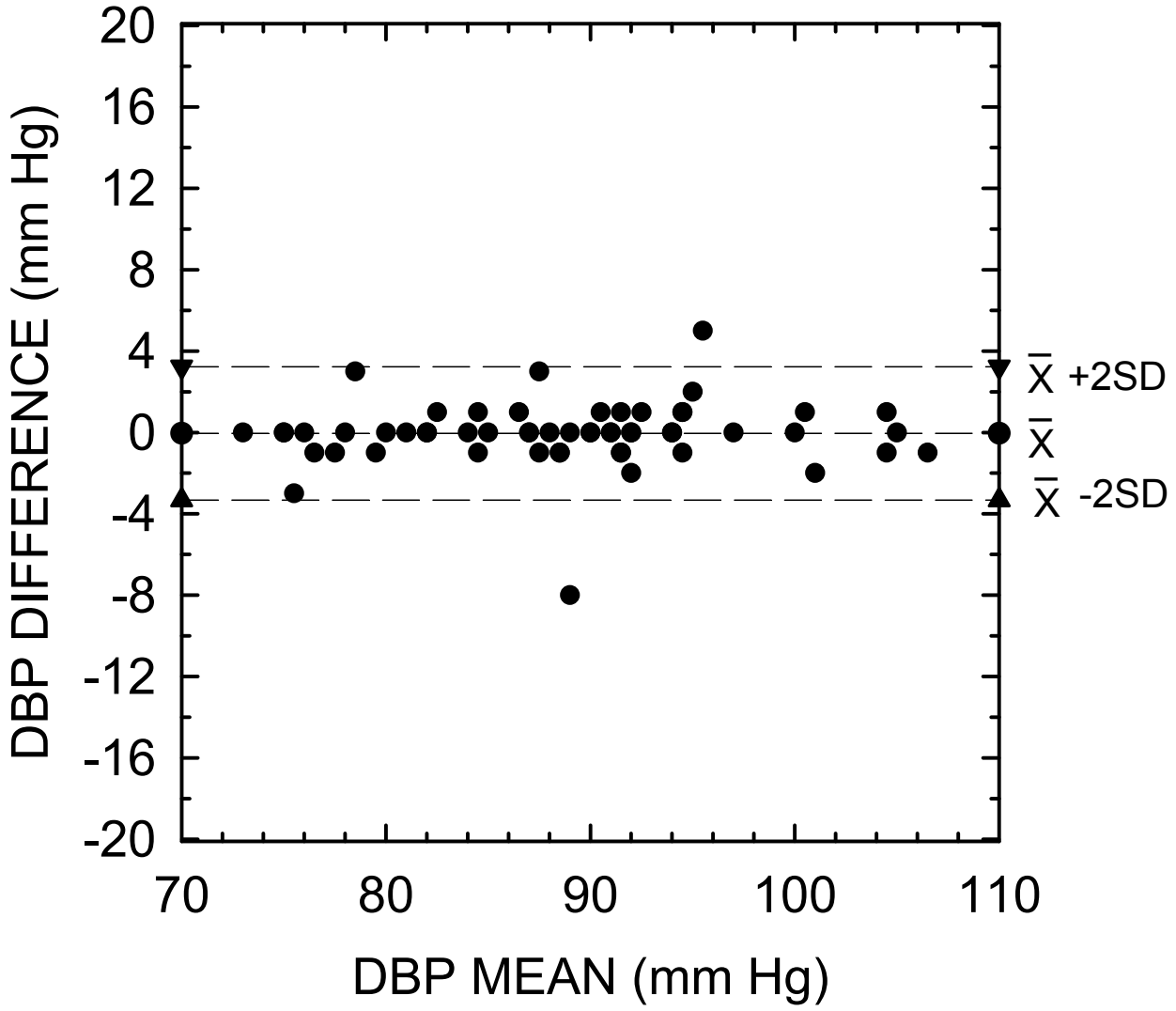
SpaceLabs Medical
The Clinical Information Company

SPACELABS 1 vs SPACELABS 2

DIASTOLIC BLOOD PRESSURE (DBP)

LABILE HYPERTENSIVE (52 yr ♂) FIELD TEST

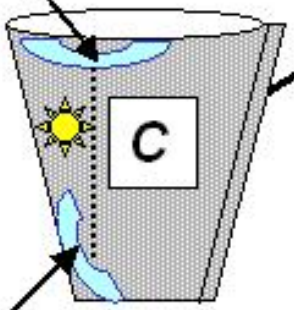
SIMULTANEOUS, SAME ARM, N = 57 TRIALS



AO-pABPM Prototype Model

***O* = *Oscillometric Transducer* ***
detects pulse △s in BP cuff

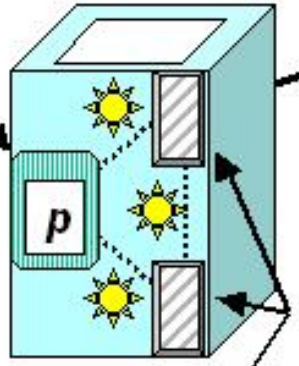
connecting pressure tube



C* = *Cone-shaped, velcro cuff* *
5 sizes: large adult, adult,
small adult, pediatric, neonatal

p = pump

A* = *Ausculatory Transducer* *
piezo-electric *curved* crystal
microphone detects K-sounds

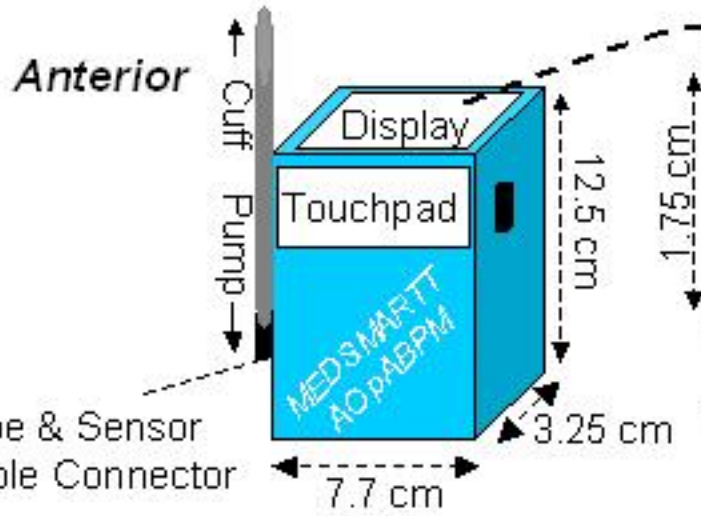


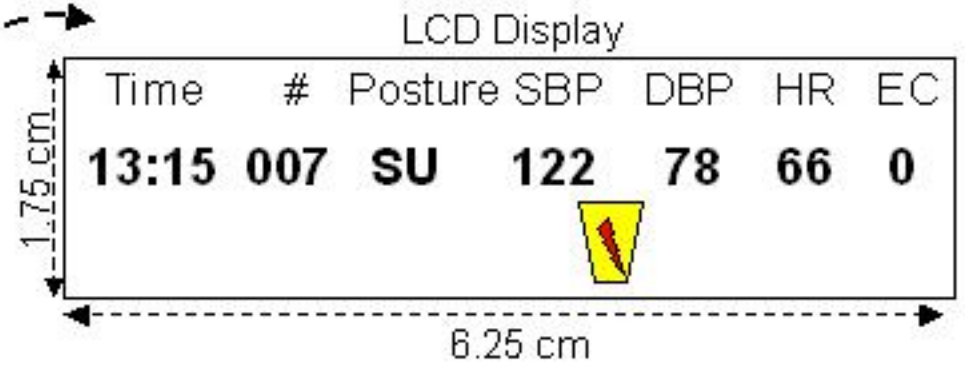
MedSmartt* **
AO-pABPM

d = distance between components
i = interference potential

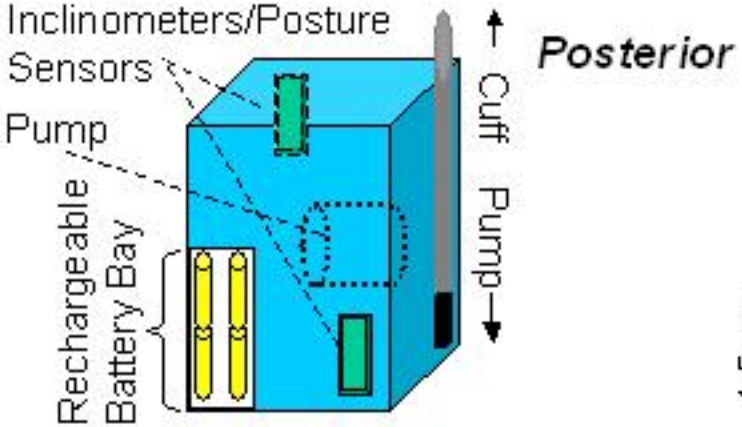
***a*$_1$, *a*$_2$ =**
accelerometers 1 & 2
detect static acceleration,
tilt = body position

*1979, **1992, ***2005-2006

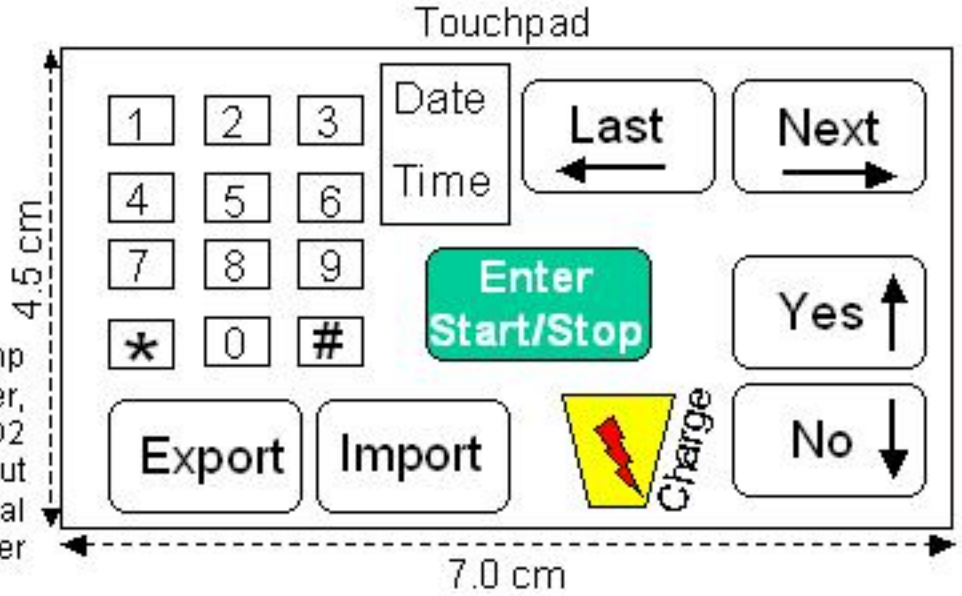




NB: Inverted from Anterior view so technical staff can view during baseline calibration and subjects during subsequent testing. The AO pABPM will have an option for blocking column display output, so that subjects may view only Time, Measurement #, Posture, and EC/Error Codes for 1 min after each field test measurement.



NB: Potential pump types: (1) Piezo-electric pump enables silent pumping & consumes little power, but currently has too low of a flow rate, (2) CO2 gas canister which has near-silent pumping but with potential safety issues, & (3) Conventional diaphragm pump which is noisier and has higher power consumption.



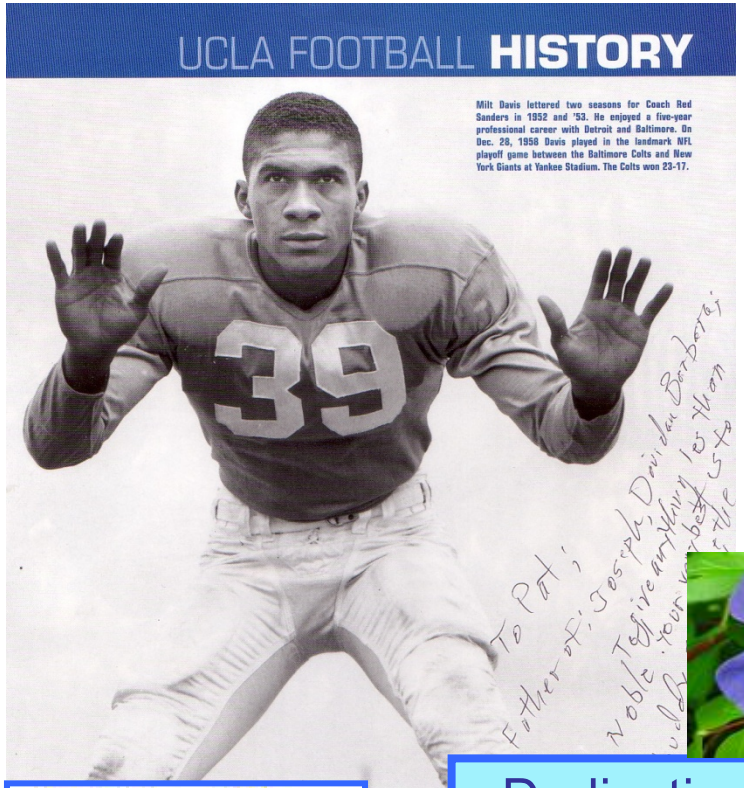
AMERICAN COLLEGE of SPORTS MEDICINE

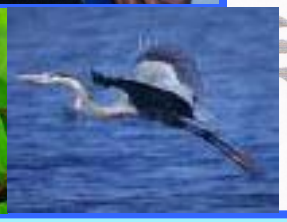
09 ANNUAL MEETING

ACSM ADVANCING

MAY 27-30

SEATTLE, WASHINGTON, USA

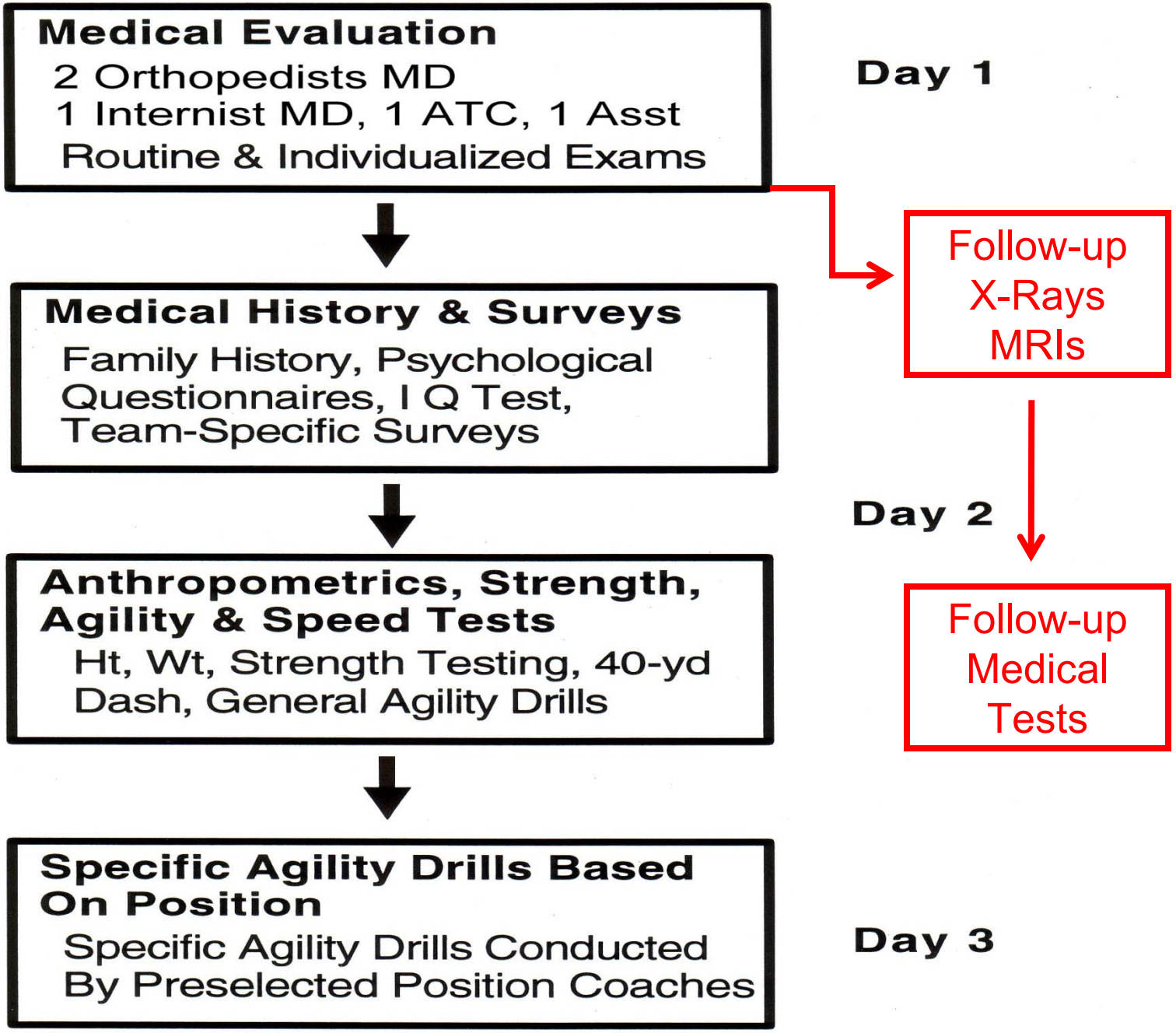




Dedication to Dr. Milton Eugene Davis
NFL All-Pro Baltimore, 30 yr NFL Scout
Professor of Zoology, Field Ornithology
& Natural History, May 31, 1929 –
September 29, 2008

GOALS

1. Provide a small sample of some of Dr. Davis' work on sports medicine injuries in NFL Combine players. We will focus on ~5-yr injury history of 314 players from 2004.
2. Describe prevalence, anatomical sites & diagnoses with an emphasis on player position in attempt to develop an injury-diagnoses-player position continuum.
3. Provide suggestions to minimize injuries & maximize NFL longevity & ultimately quality of life after retirement.
4. Help younger athletes who play football & their coaches & allied health & medical practitioners.
5. Provide impetus to move from descriptive to more causal mechanistic & integrative research with input from biomechanists, physiologists, physicians, NATA & PT.


Medical Evaluation
2 Orthopedists MD
1 Internist MD, 1 ATC, 1 Asst
Routine & Individualized Exams
Day 1
Follow-up
X-Rays
MRIs
Medical History & Surveys
Family History, Psychological
Questionnaires, I Q Test,
Team-Specific Surveys
Day 2
Anthropometrics, Strength,
Agility & Speed Tests
Ht, Wt, Strength Testing, 40-yd
Dash, General Agility Drills
Follow-up
Medical
Tests
Specific Agility Drills Based
On Position
Specific Agility Drills Conducted
By Preselected Position Coaches
Day 3

Medical History, DL Major University

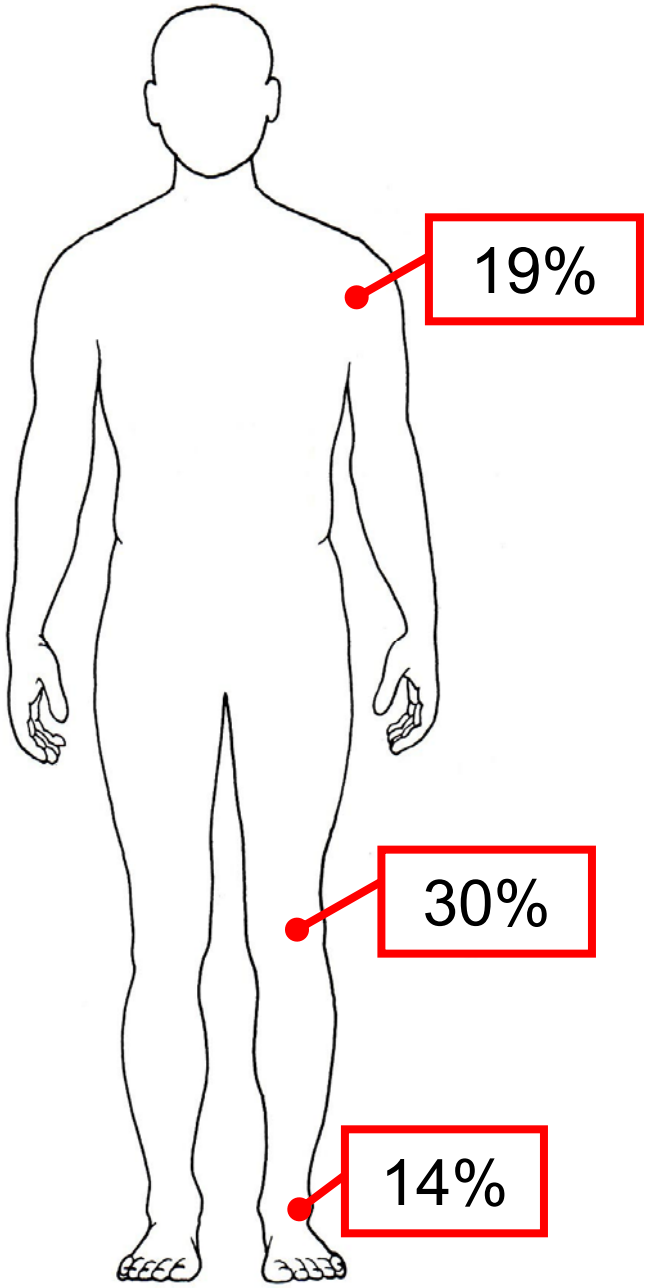
- **3/04 L Ankle Athroscopy, Removal Symptomatic Os Trigonum, 10/03 L High Ankle Sprain, MRI Peroneal Tendonosis, Split in Peroneus Brevis, 10/02 R Foot 5th Metatarsal Jones Fracture, ORIF, 02/03 R Wrist Chronic Pain, Surgical Cyst Removal, 02/00 R Lunotriquetral Ligament Tear, Surgical Debridement, 8/99 L Knee Patellar Tendonitis, Probable Grade 2**
- ***4/2 ORTHO, MED 0***

CODED: 17,9, 17,3, 17,7, 17,4, 11,9, 18,5, 11,4, 15,7

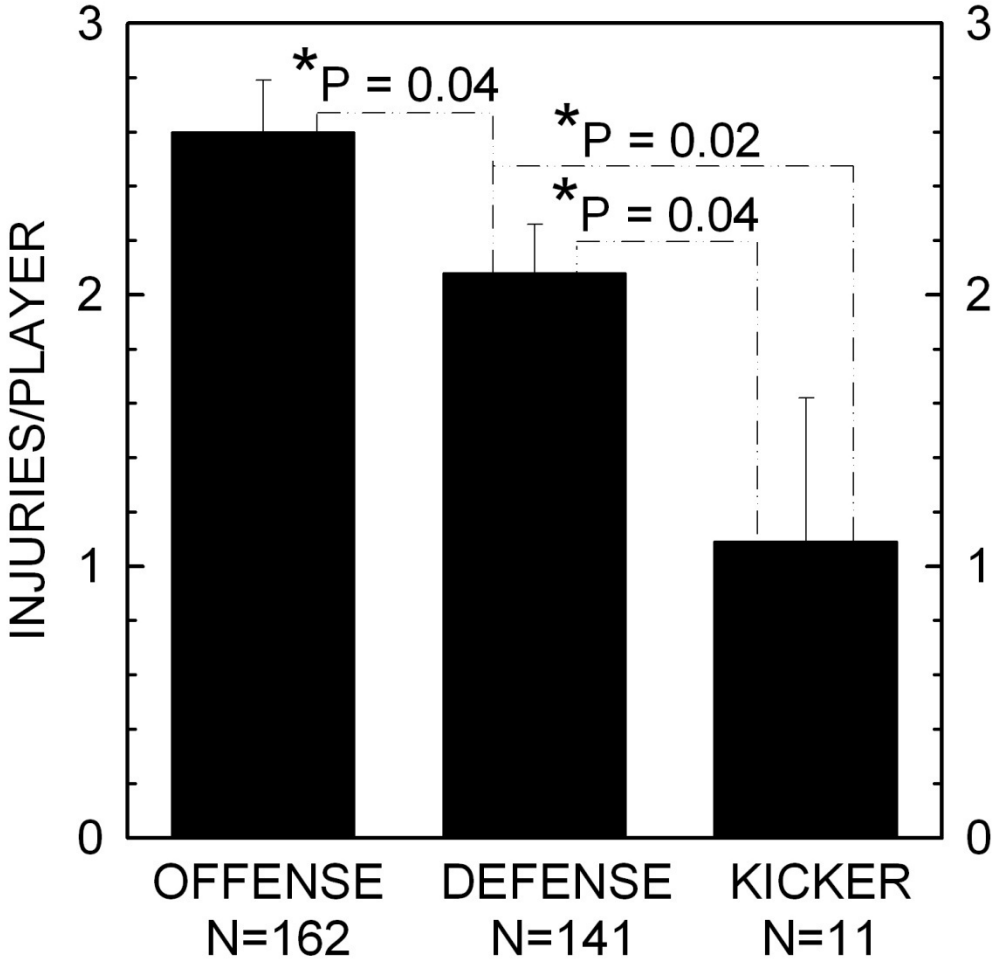
726 Documented Injuries
in 314 Players
2.3 Injuries/Player
Range: 0 – 10 Injuries
63% of Players ≥ 1 Injury

7%	1 Injury
9%	2 Injuries
29%	3 or 4 Injuries
18%	≥ 5 Injuries

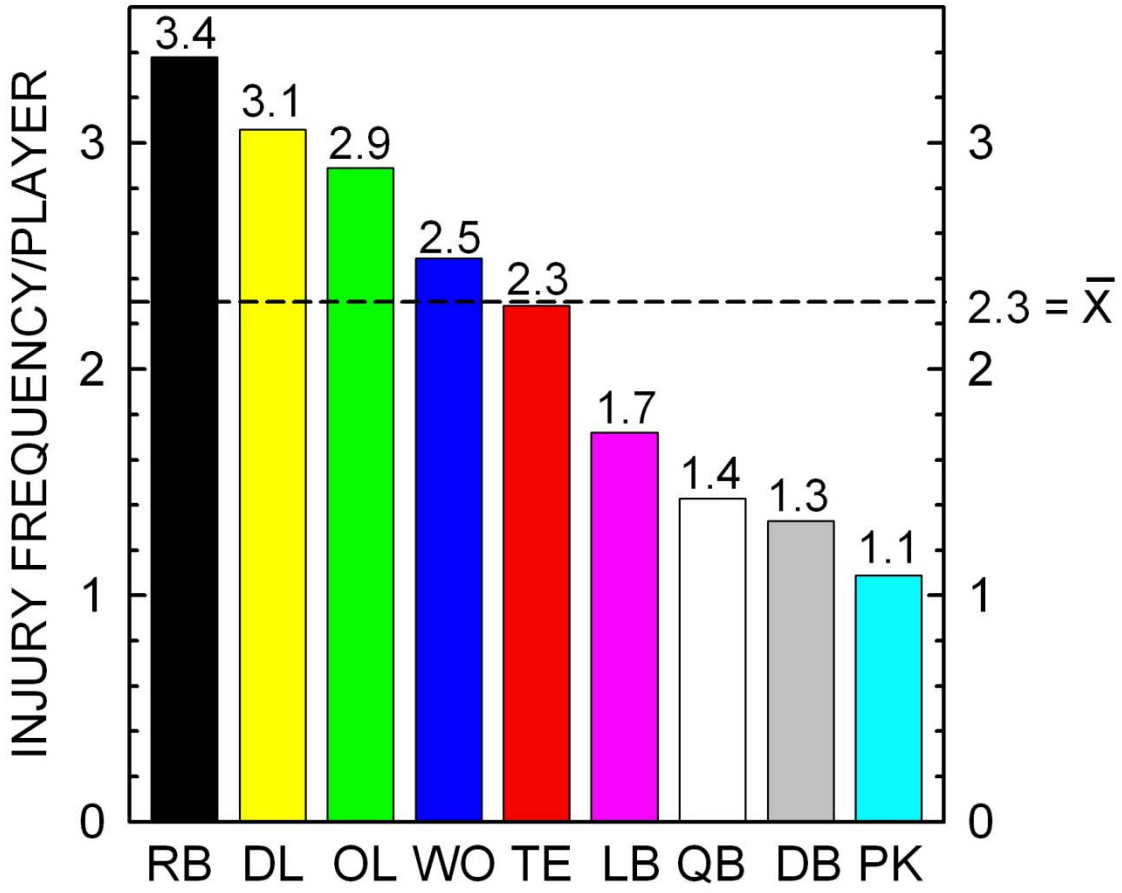
NB: 3 yr prior, 1.4 Injuries/Player
58% of Players ≥ 1 Injury



INJURIES/PLAYER BY PLATOON
NFL COMBINE 2004, N = 314

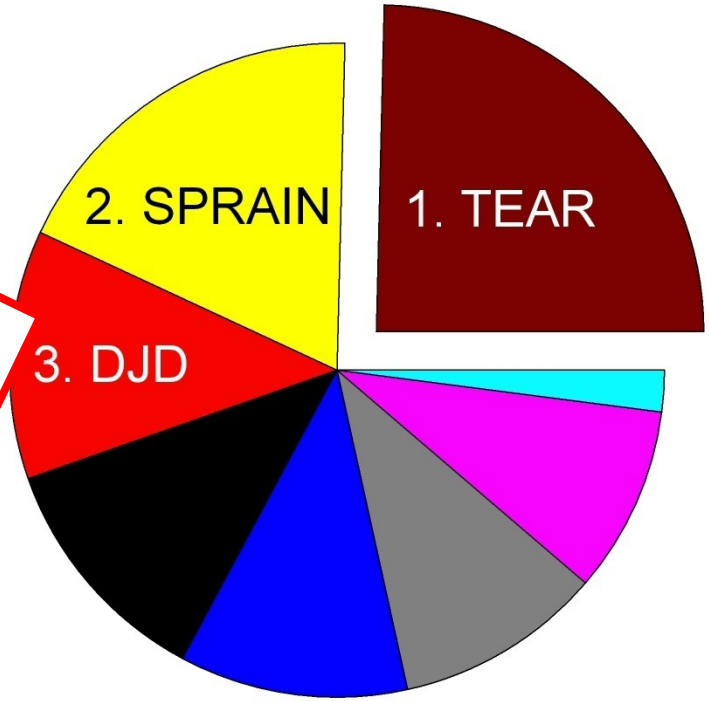


INJURY FREQUENCY/PLAYER BY POSITION
NFL COMBINE 2004, N = 726/314, 2.3/PLAYER

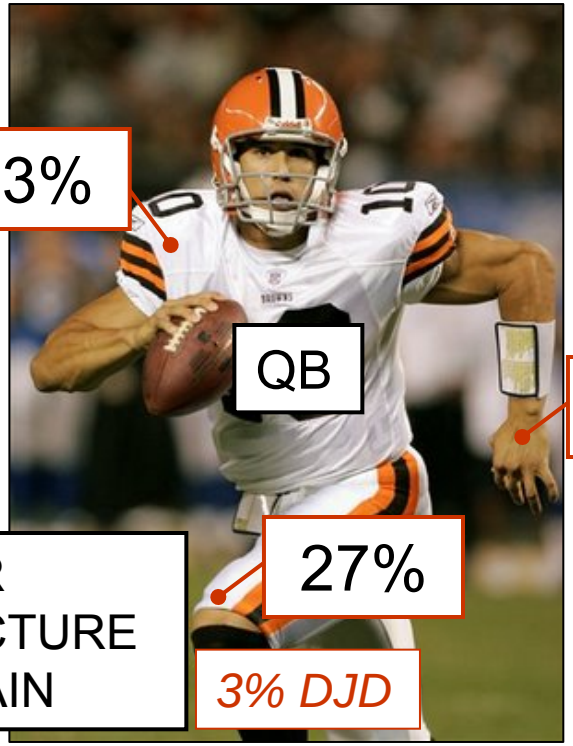


INJURY DIAGNOSES
NIC 2004, 314 PLAYERS
726 INJURIES OVER 5 YR

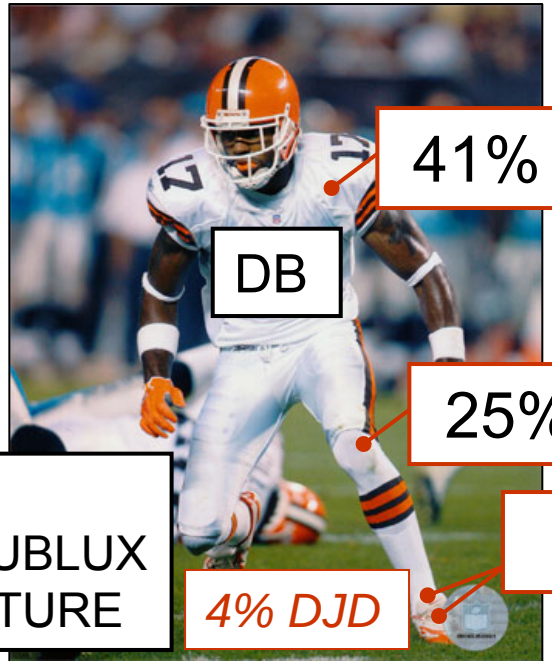
NB: 1st time in top 3!

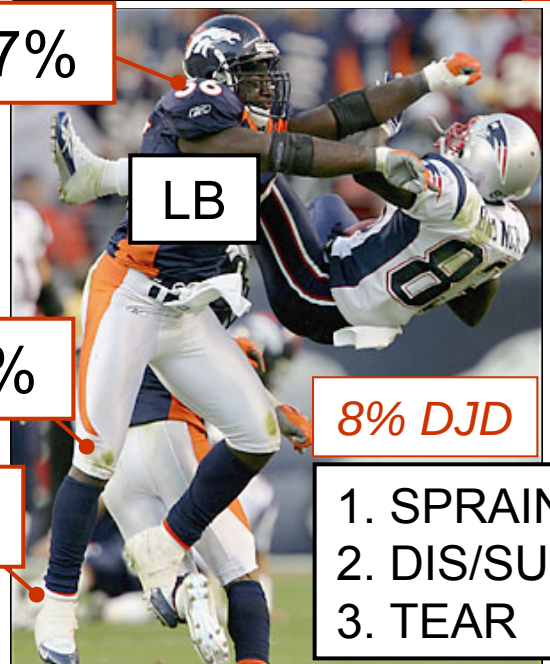


- 24% TEAR
- 18% SPRAIN
- 12% ARTHRITIS/DJD
- 12% DISLOCATION/SUBLUX
- 11% REPETITIVE TRAUMA
- 10% FRACTURE
- 9% INFLAMMATION NOT DJD
- 2% STRAIN


23%
QB
20%
27%
1. TEAR
2. FRACTURE
3. SPRAIN
3% DJD

16%
OL
23%
15% DJD
1. TEAR
2. SPRAIN
3. DIS/SUBLUX
16%


41%
DB
25%
6%
4% DJD
1. TEAR
2. DIS/SUBLUX
3. FRACTURE


27%
LB
27%
8% DJD
19%
1. SPRAIN
2. DIS/SUBLUX
3. TEAR

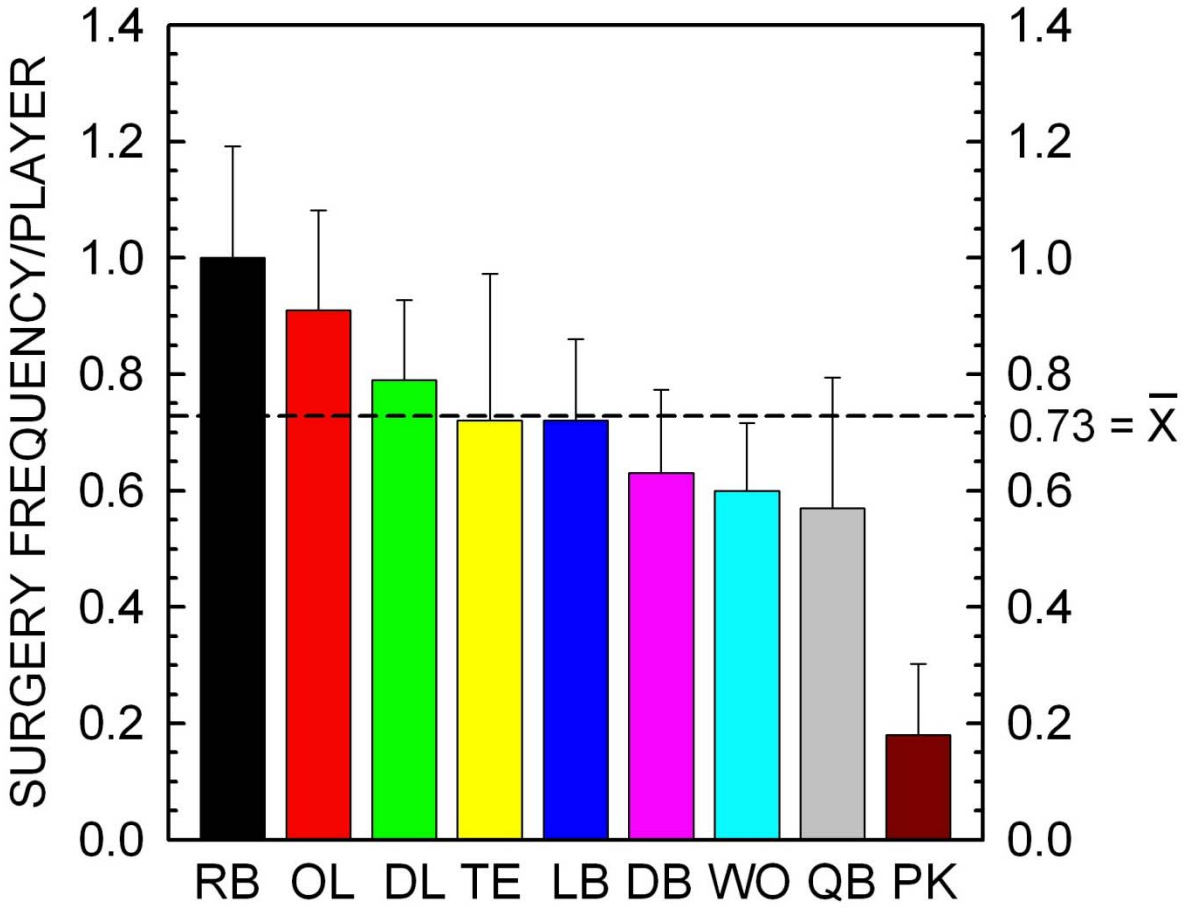
JARES
78
28
25
53
BURTON
98
4
29

© 1998 NUCLEUS COMMUNICATIONS, INC.—ATLANTA

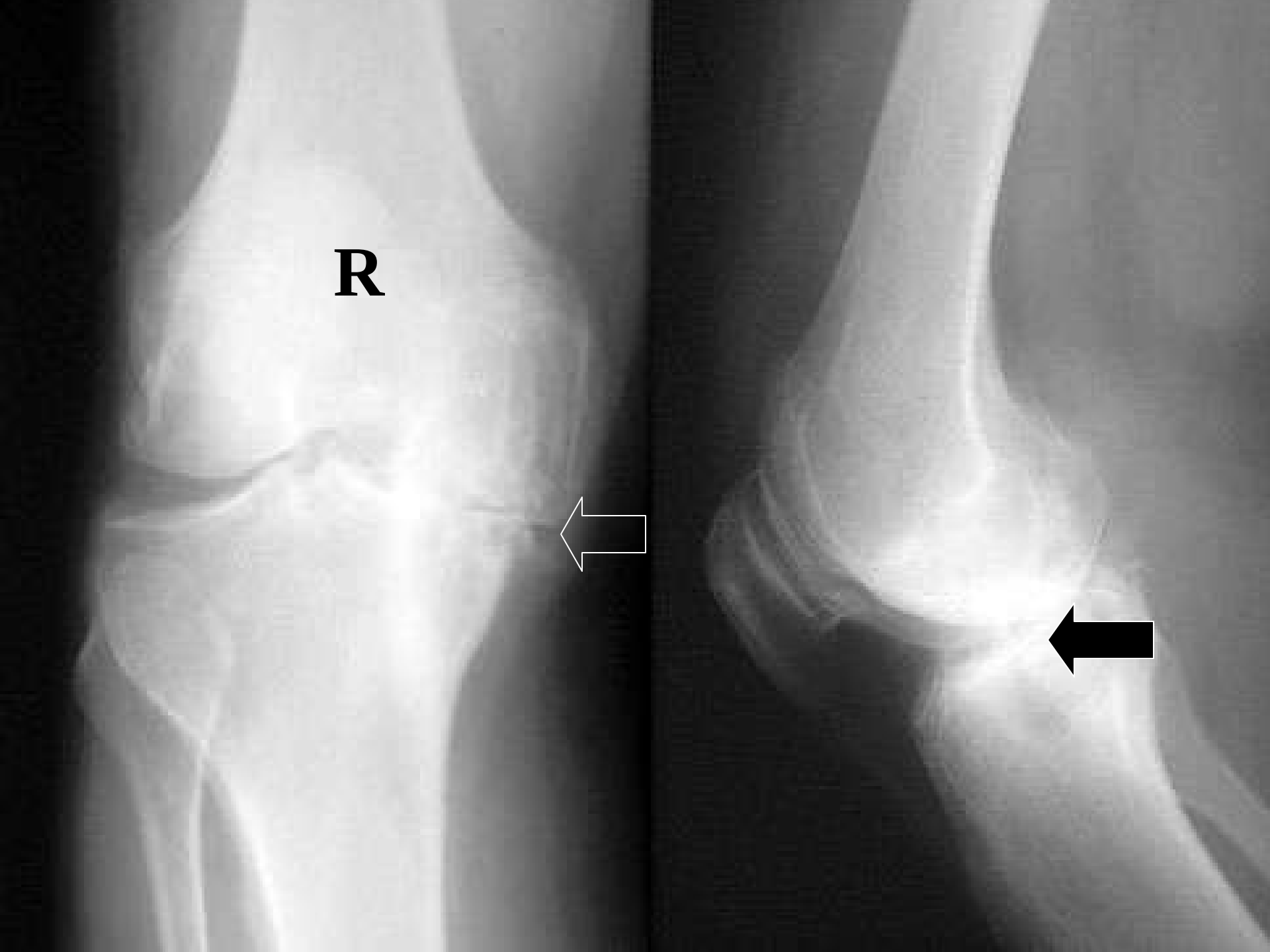
139 of 314 or ~ 44% had 228 surgeries ≡ 0.73 surgeries/player for all 314 players:

1 Surgery:	**25%**	
2 Surgeries:	**13%**	**20%**
3 Surgeries:	**5%**	
4 Surgeries:	**2%**	

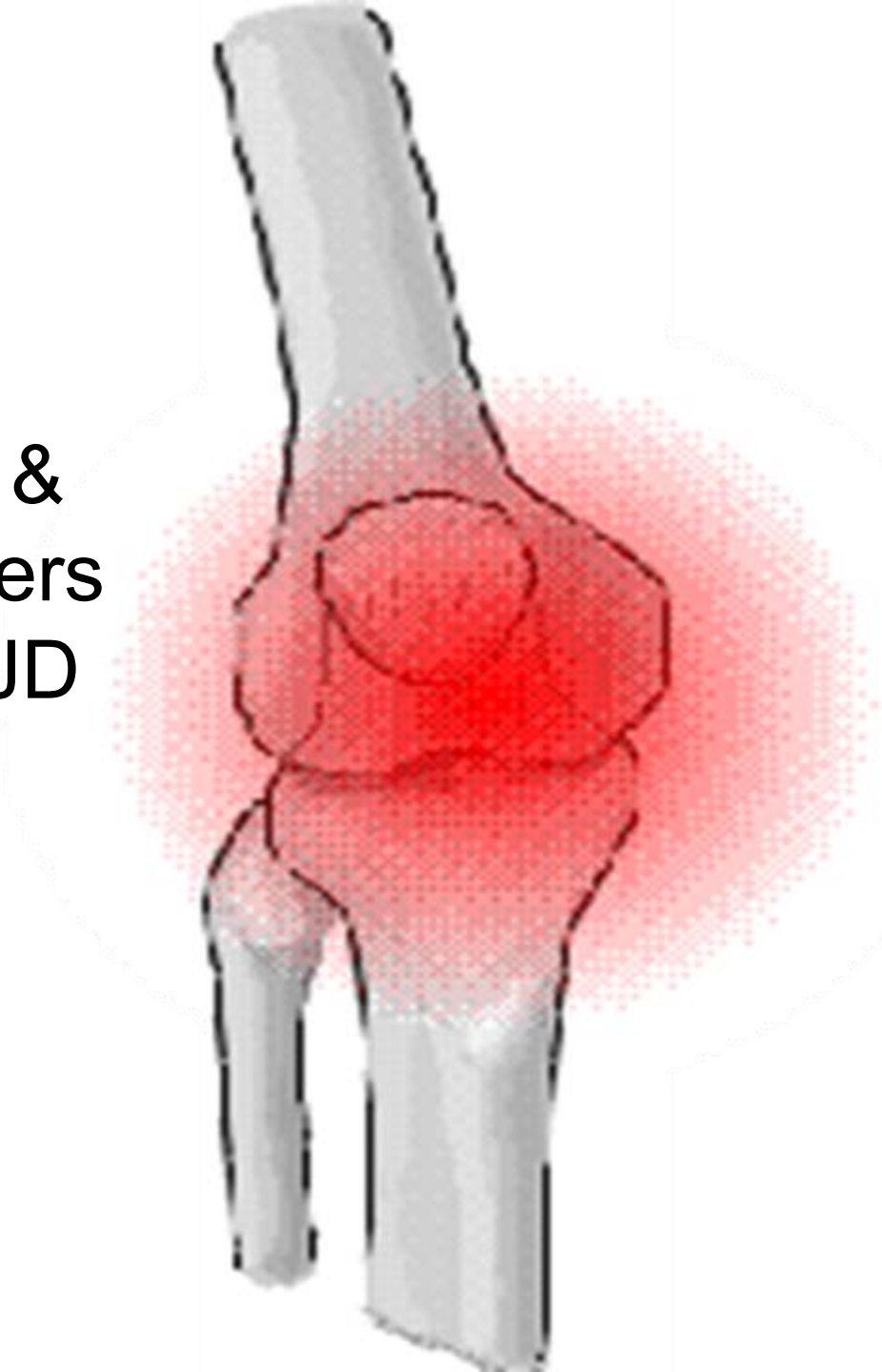
SURGERY FREQUENCY/PLAYER BY POSITION
NFL COMBINE 2004, N = 228/314, 0.73/PLAYER



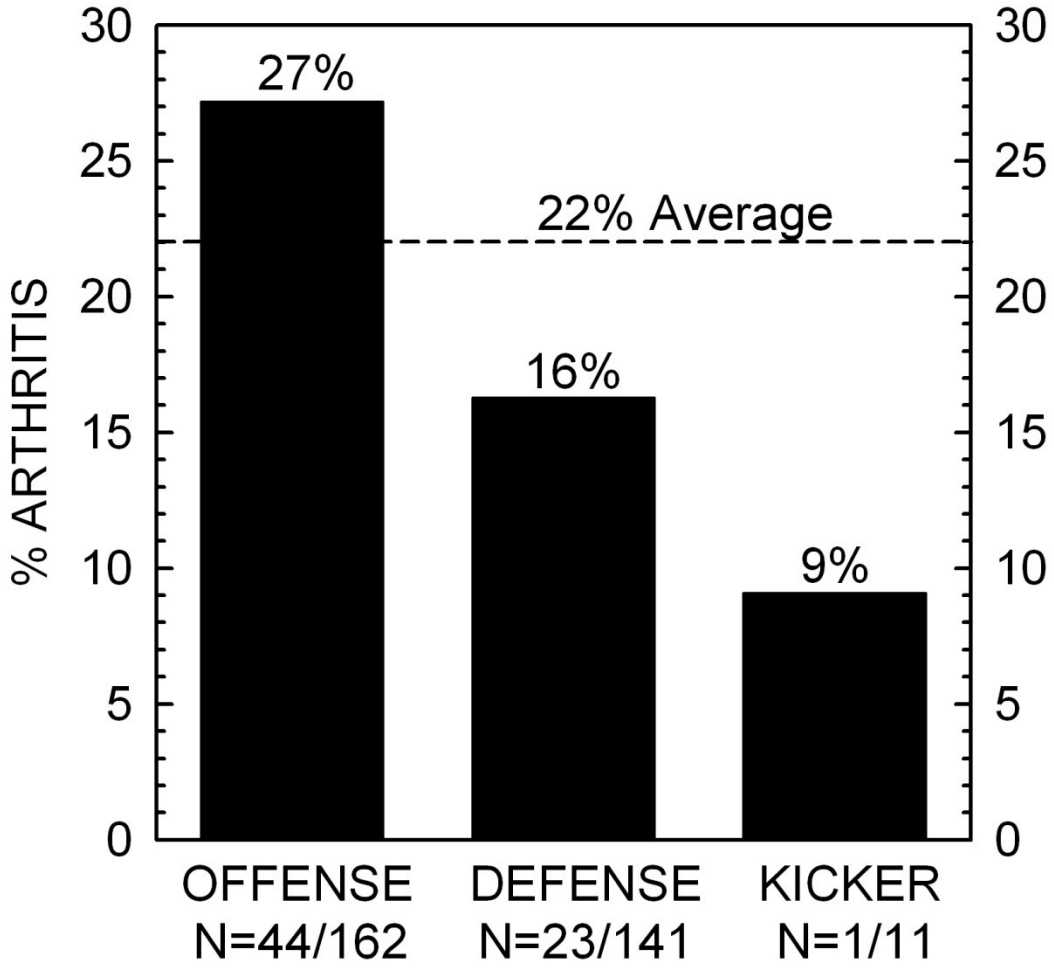
MADISON
29
24


R

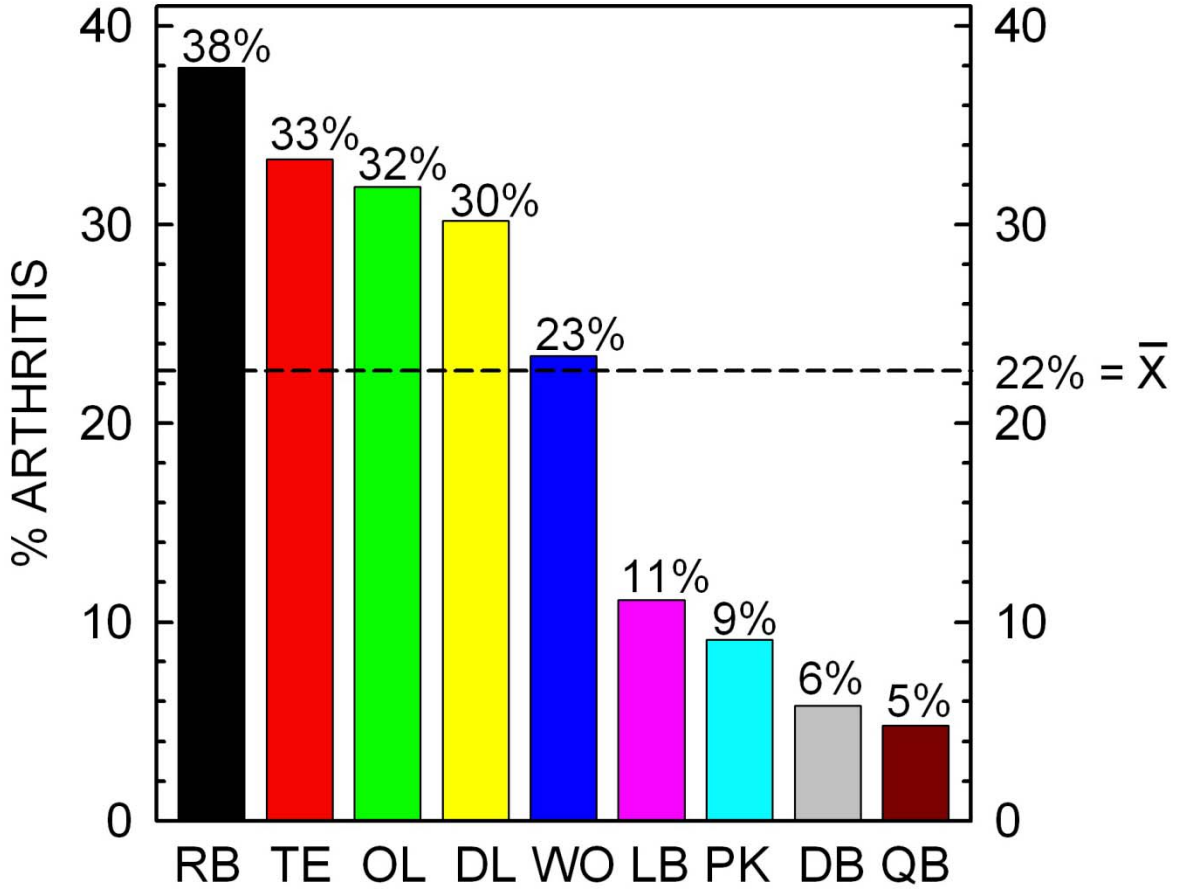
12% of All Players &
22% of Injured Players
Have Significant DJD
or Arthritis



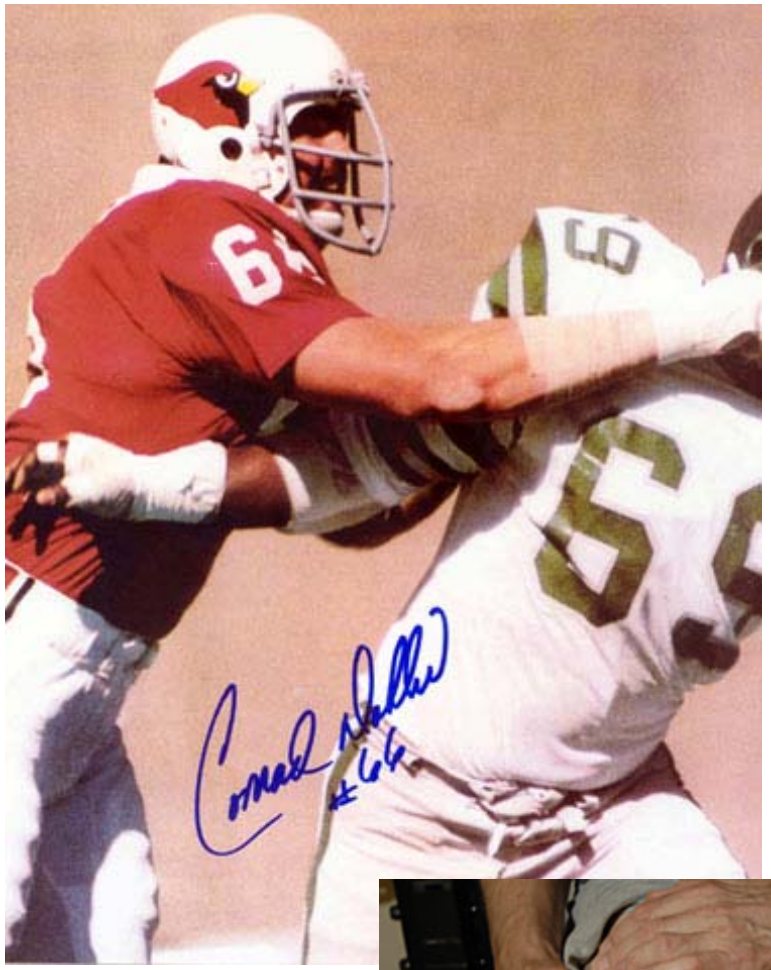
% PLAYERS WITH ARTHRITIS BY PLATOON
NFL COMBINE 2004, N = 68/314, 22%

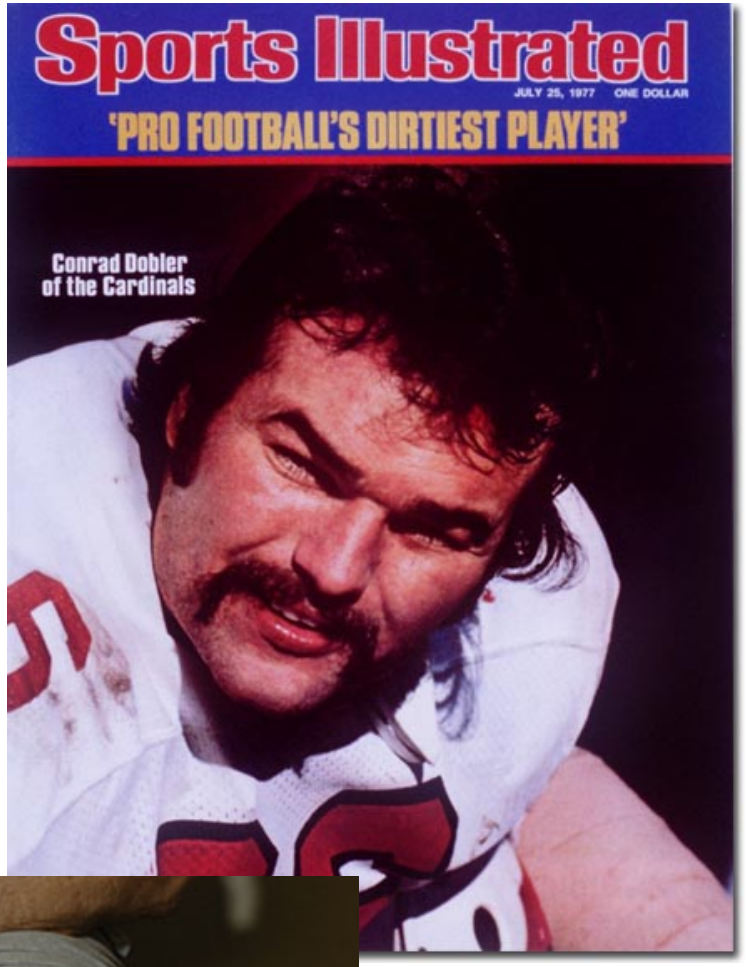


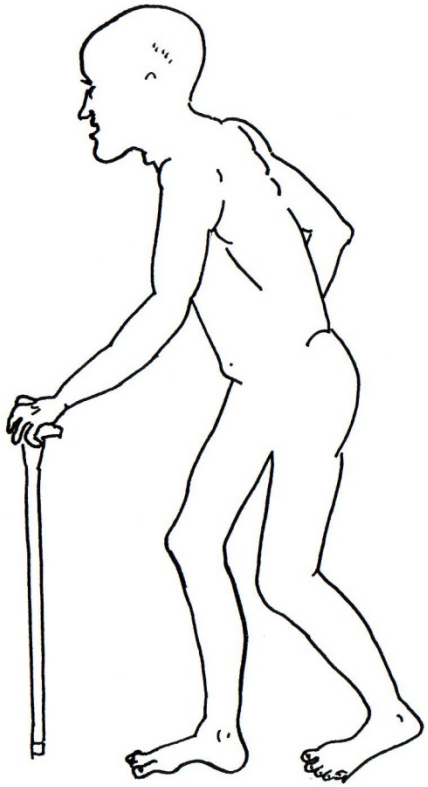
% PLAYERS WITH ARTHRITIS BY POSITION
NFL COMBINE 2004, N = 68/314, 22%



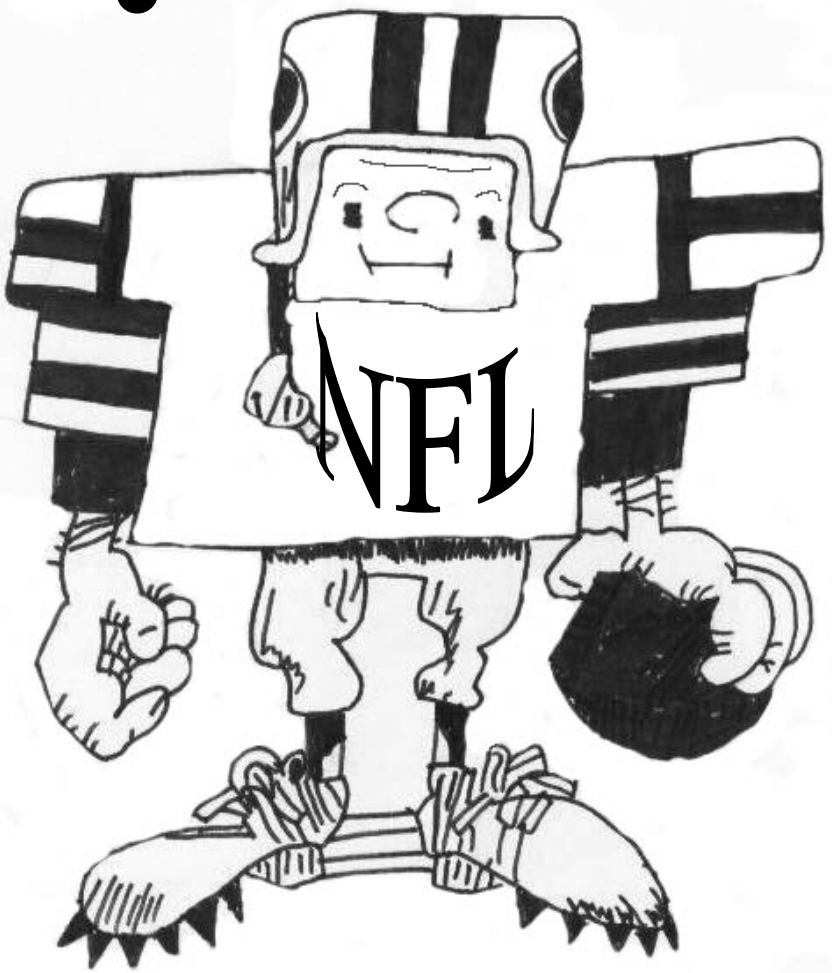
FUTURE?

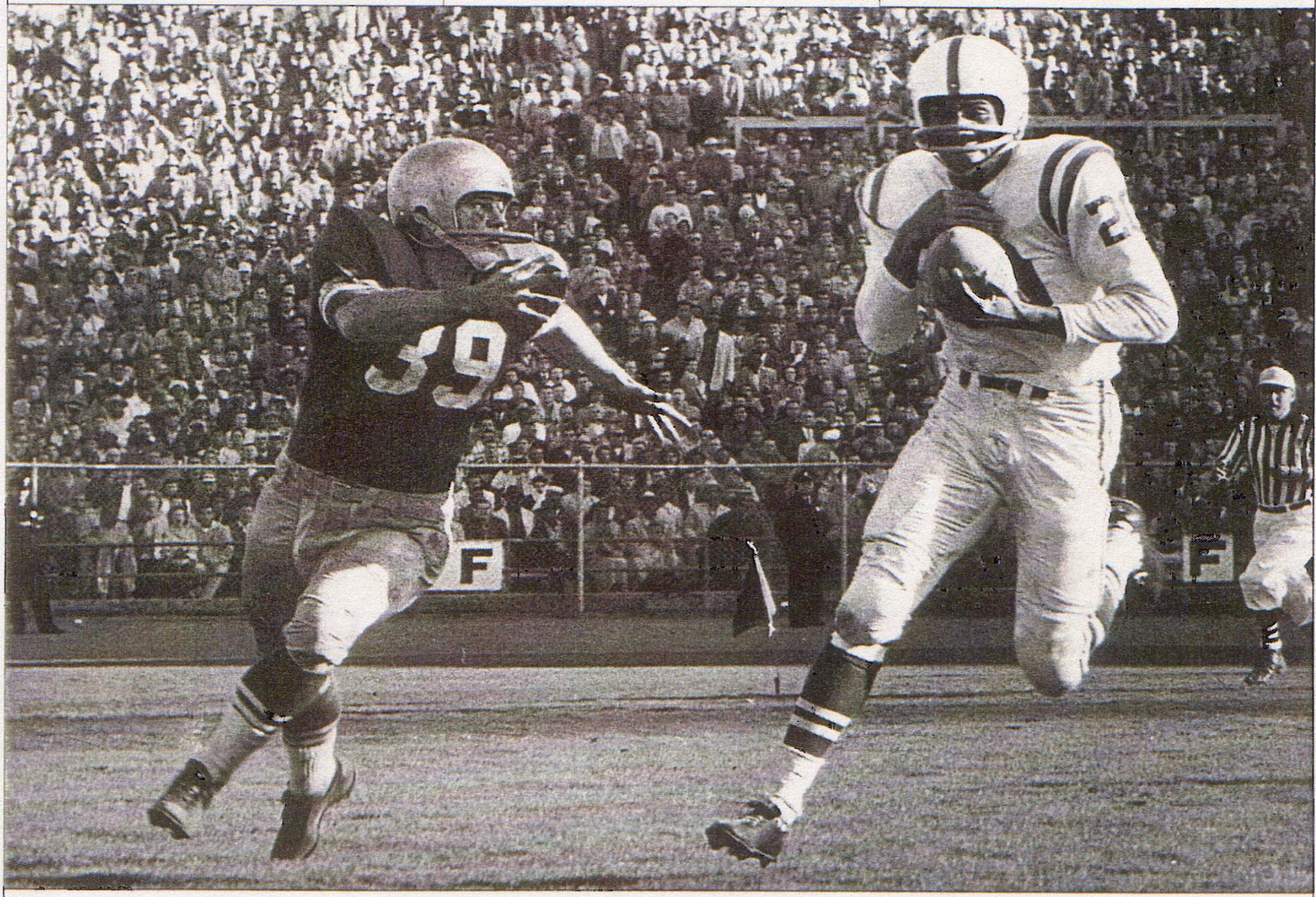



Sports Illustrated
JULY 25, 1977 ONE DOLLAR
'PRO FOOTBALL'S DIRTIEST PLAYER'
Conrad Dobler
of the Cardinals



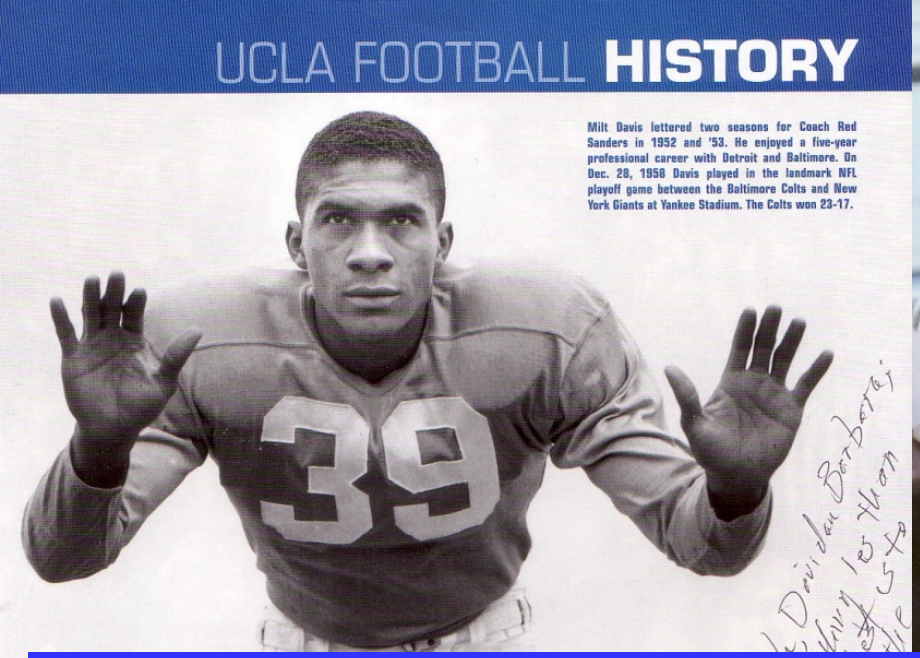
?


NFL



■ No NFL player ever has collected interceptions at a faster rate than Baltimore's Milt Davis.

Frank Rippon



TAKE-AWAY POINTS FROM DR. DAVIS:

1. Over 3 yr, the surgery rate remained relatively constant (0.7 surgeries/player) while the injury rate increased from 1.4 to 2.3 injuries/player (↑ 64%).

2. An injury rate continuum spans from highest near the point of attack -- RB (3.4/player), OL (3.1/player) & DL (2.9/player) – to lowest further from the point of attack: PK (1.1), DB (1.3) & QB (1.4).

3. The knee, shoulder & ankle are primary sites of injury, while primary diagnoses include tears, sprains & degenerative joint disease.

4. Over 3 yr, the % of injured players with documented degenerative arthritis increased from 8% to 12% (↑ 50%) which seems to mirror the increased injury rate.

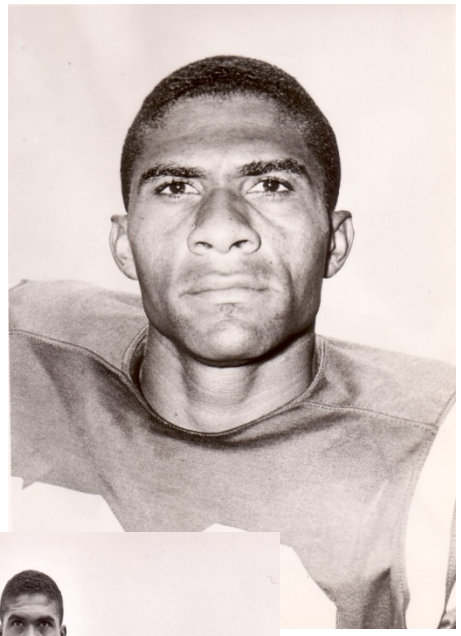
5. While anatomical sites of injury appear identical to earlier results, diagnoses appear to be shifting toward more arthritis. We suspect that this trend is likely to impact NFL participation and longevity. We hope to continue Dr. Davis' work with this as a focus for future investigations.

DISCUSSION

Medical History, DB, 8th Round!

- **No significant injuries on arrival to NFL**
- **1956 L Hand 1st,2nd,3rd Metacarpal Fracture**
- **1957 R Hand 2nd,3rd,4th Metacarpal Fracture**
- **1957 Nose Fracture**
- **1957 R Hand 1st Metacarpal Fracture**
- **1957 R Knee ACL Sprain**
- **1958 L Knee ACL Sprain**
- **1958 L Foot 3rd Metatarsal Fracture**
- **1959 L Hip Fracture**

Participation 95-100% for all yr



1^0 MEDICAL STATUS OF PLAYERS PRIOR TO NFL?

2^0 MULTIPLE VARIABLES:

MEDICAL

PHYSICAL

PERFORMANCE

→ Participation

→ Longevity

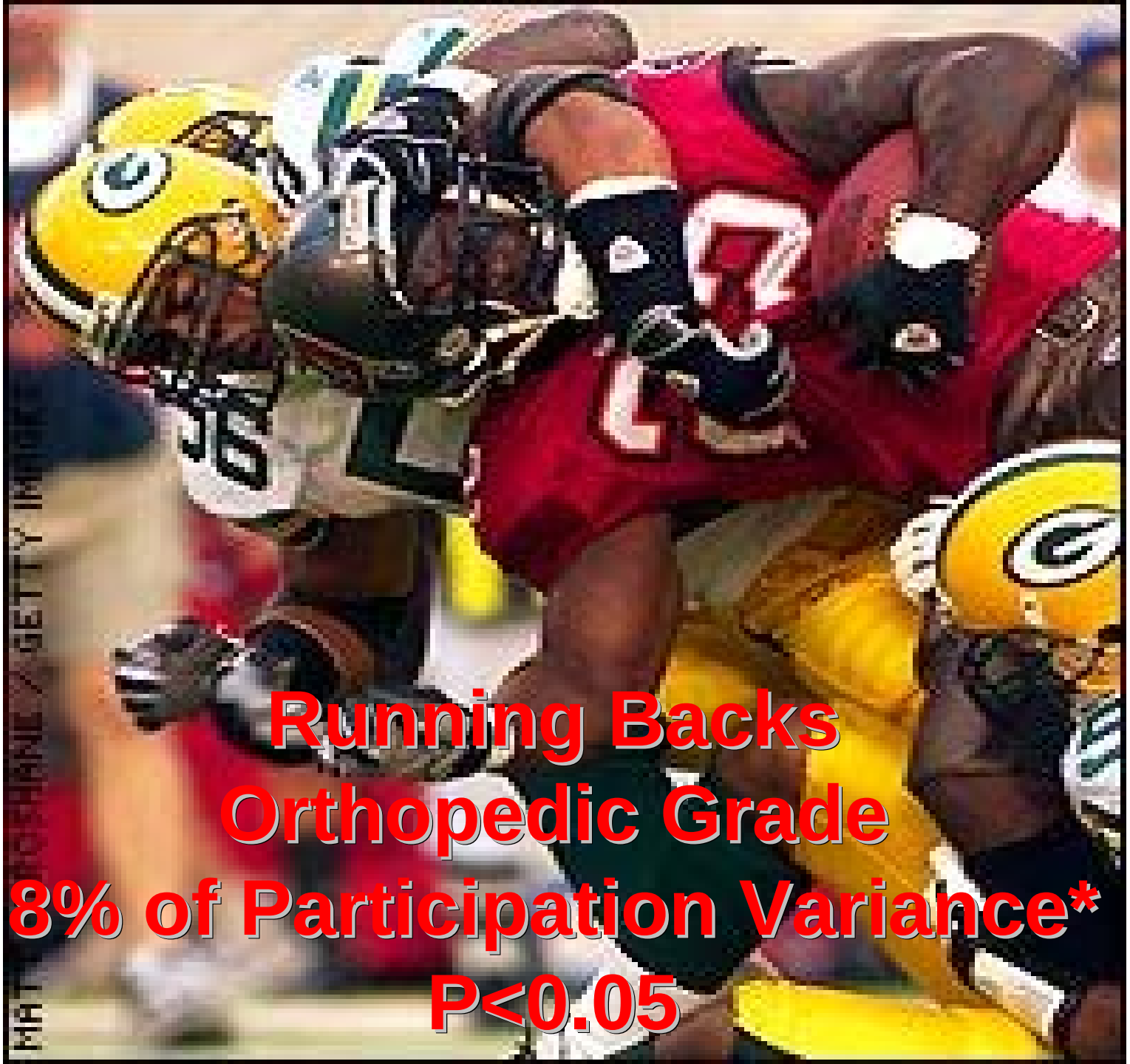
→ Productivity

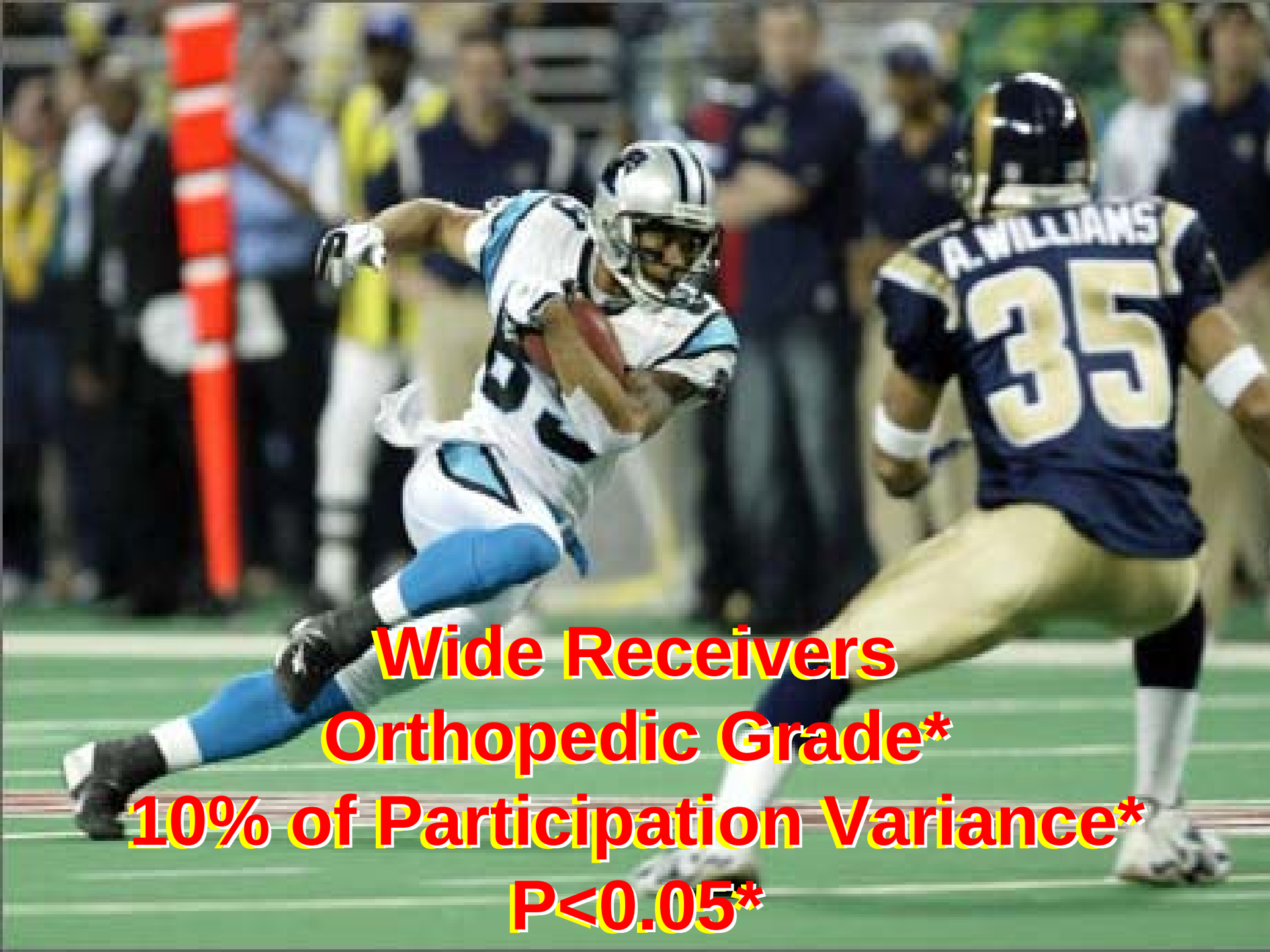
LONGEVITY?

1. 15% of players in the NFL (275/1889) are rookies in the NFL, that is with no prior experience. Only 2.9% (55/1889) have 1 year experience, while 15% (284/1889) have 2 years experience, indicating a significant cut-point/longevity threshold > rookie yr.
2. ≤ 7% of players make it longer than 10 yr in the NFL, and < 2% 13 yr or longer. Player position rather than any significant medical variable with the exception of RB, WO, and LB, appears to be more of a determinant in longevity. Of course, there are many other intrinsic variables which may prove difficult to measure.

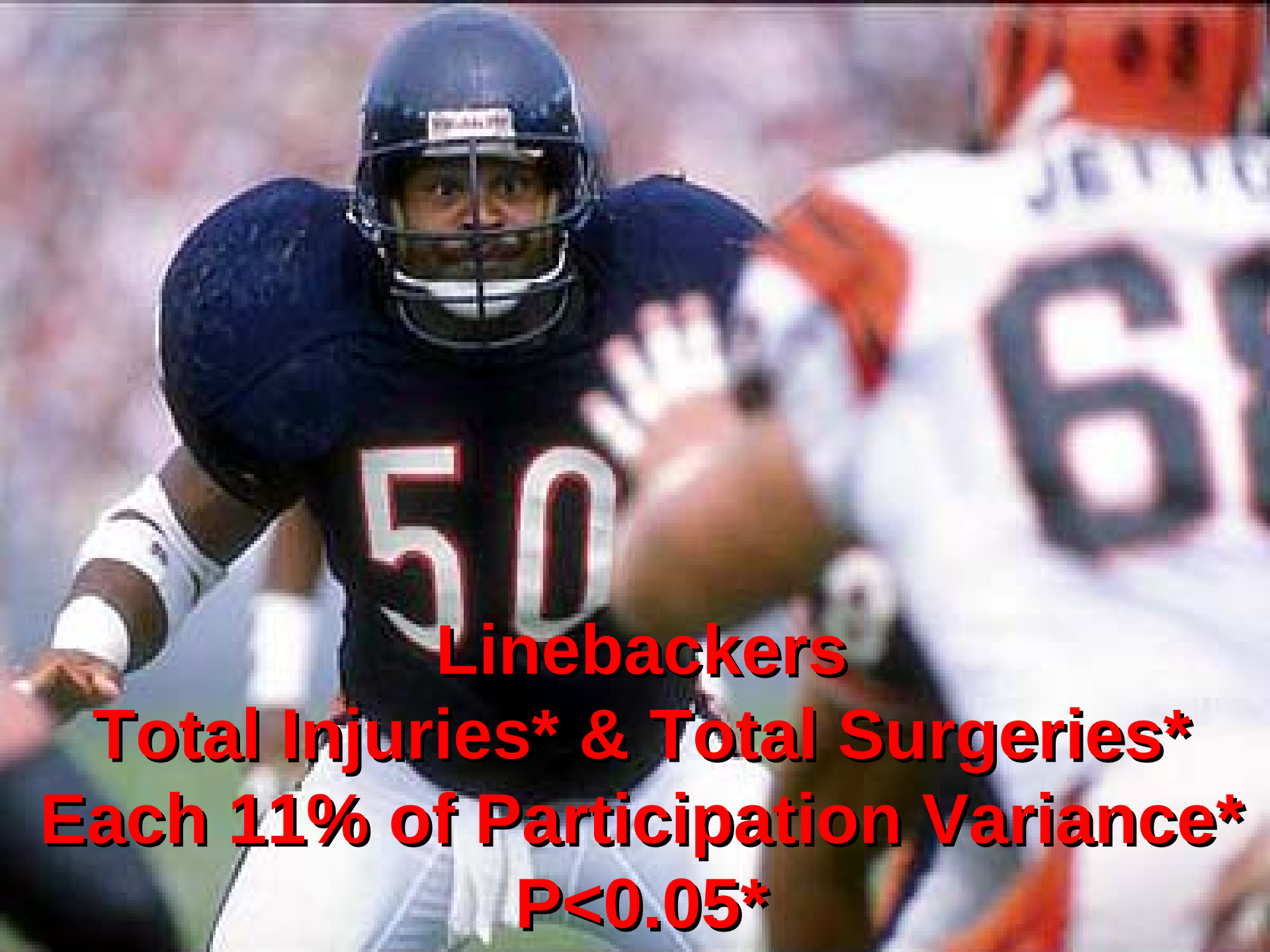
From Our Past Research Which Seems To Be Verified by Present Ongoing Analyses

1. For offensive players, only for RB and WO do any of the medical variables make a difference in predicting future participation. Orthopedic Grade and Total # of Injuries provide a small degree of predictability (8-11%).
2. For defensive players, only for LB do total number of injuries & total number of surgeries offer a marginal degree of predictability (11%).


Running Backs
Orthopedic Grade
8% of Participation Variance*
P<0.05

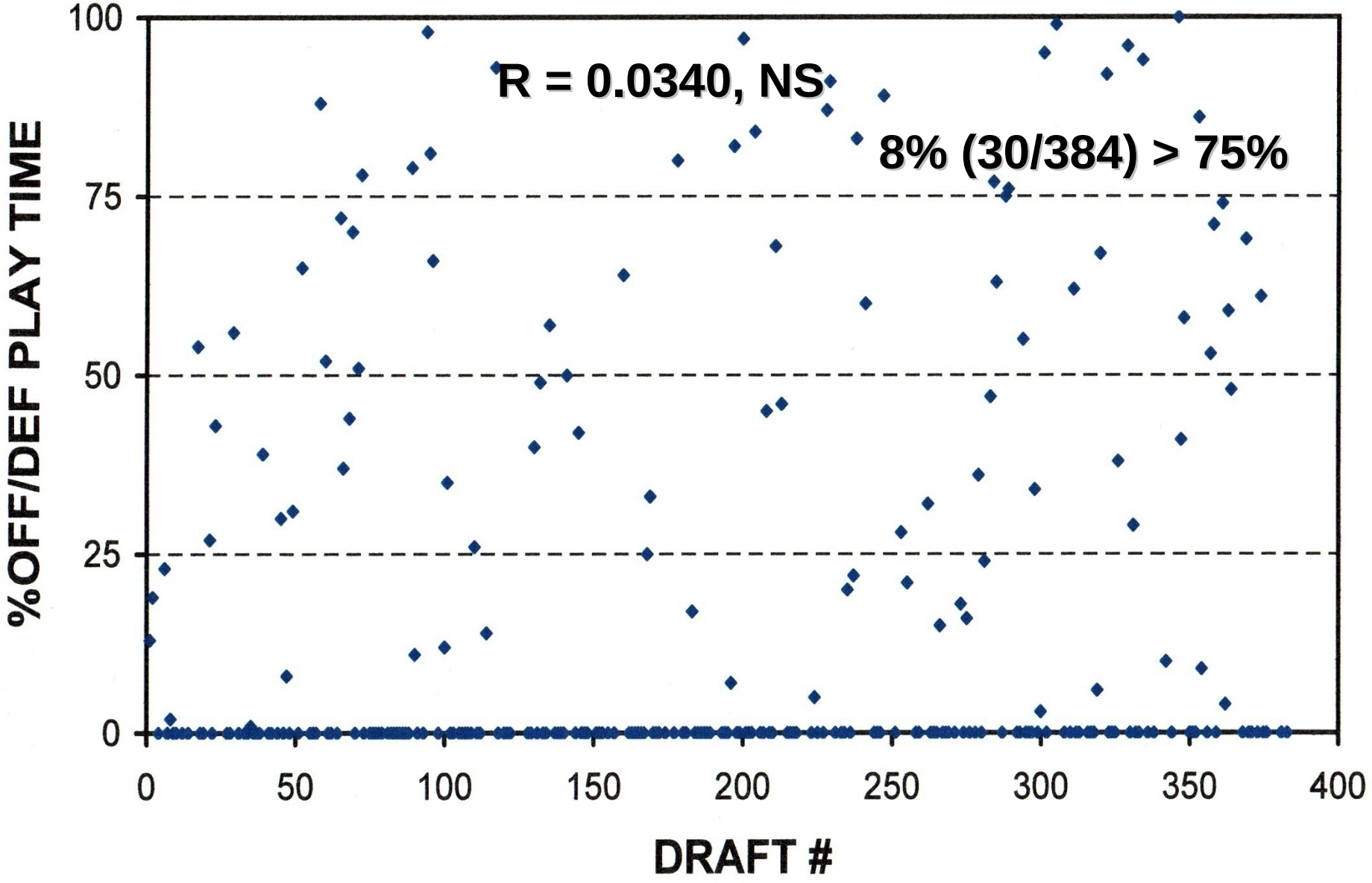


Wide Receivers
Orthopedic Grade*
10% of Participation Variance*
P<0.05*

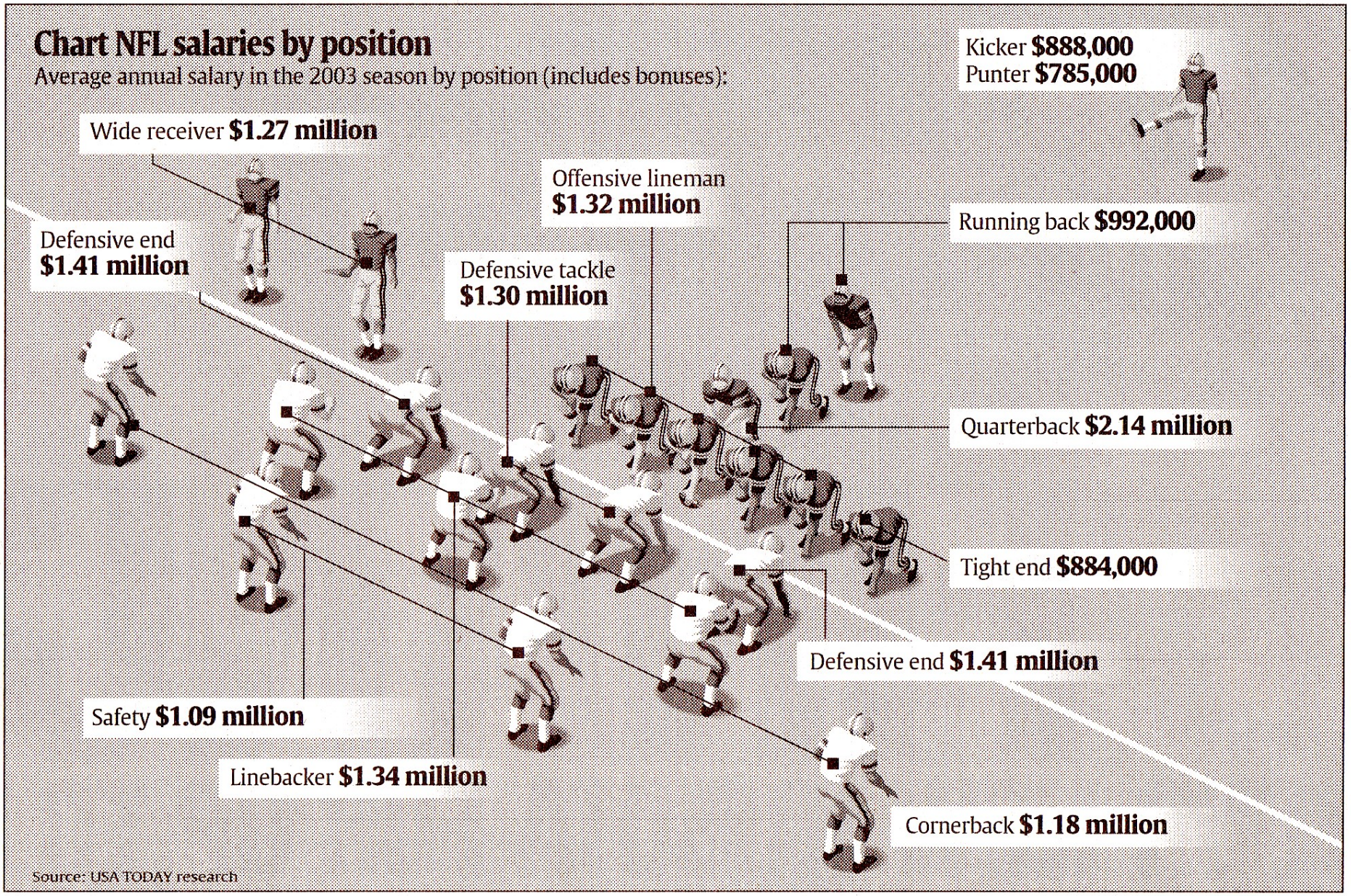


Linebackers
Total Injuries* & Total Surgeries*
Each 11% of Participation Variance*
P<0.05*

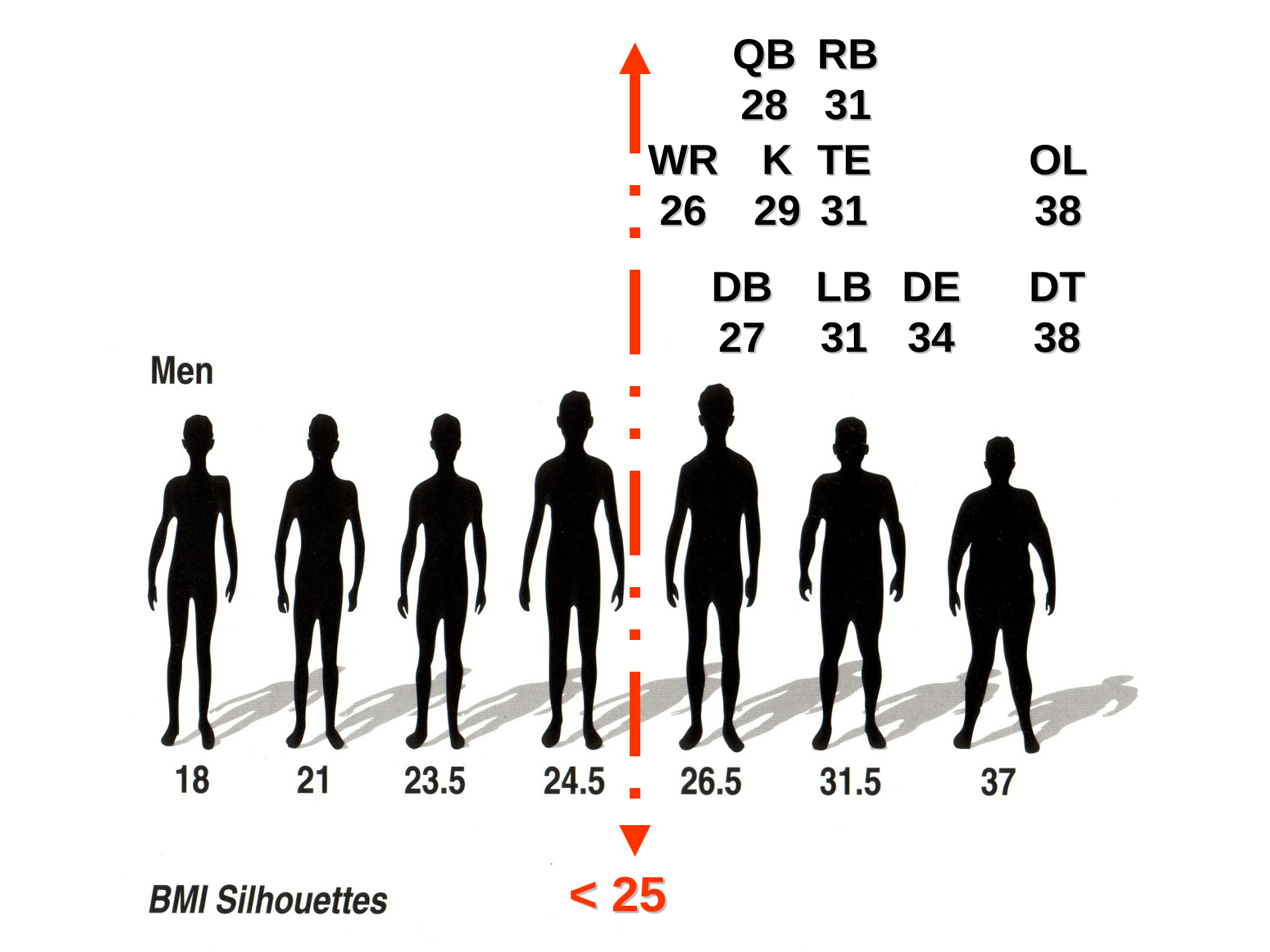
%O/D PLAY TIME VS DRAFT #, YR 2001



National Football League salaries



By Sam Ward, USA TODAY


QB RB
28 31
WR K TE OL
26 29 31 38
DB LB DE DT
27 31 34 38
Men
18
21
23.5
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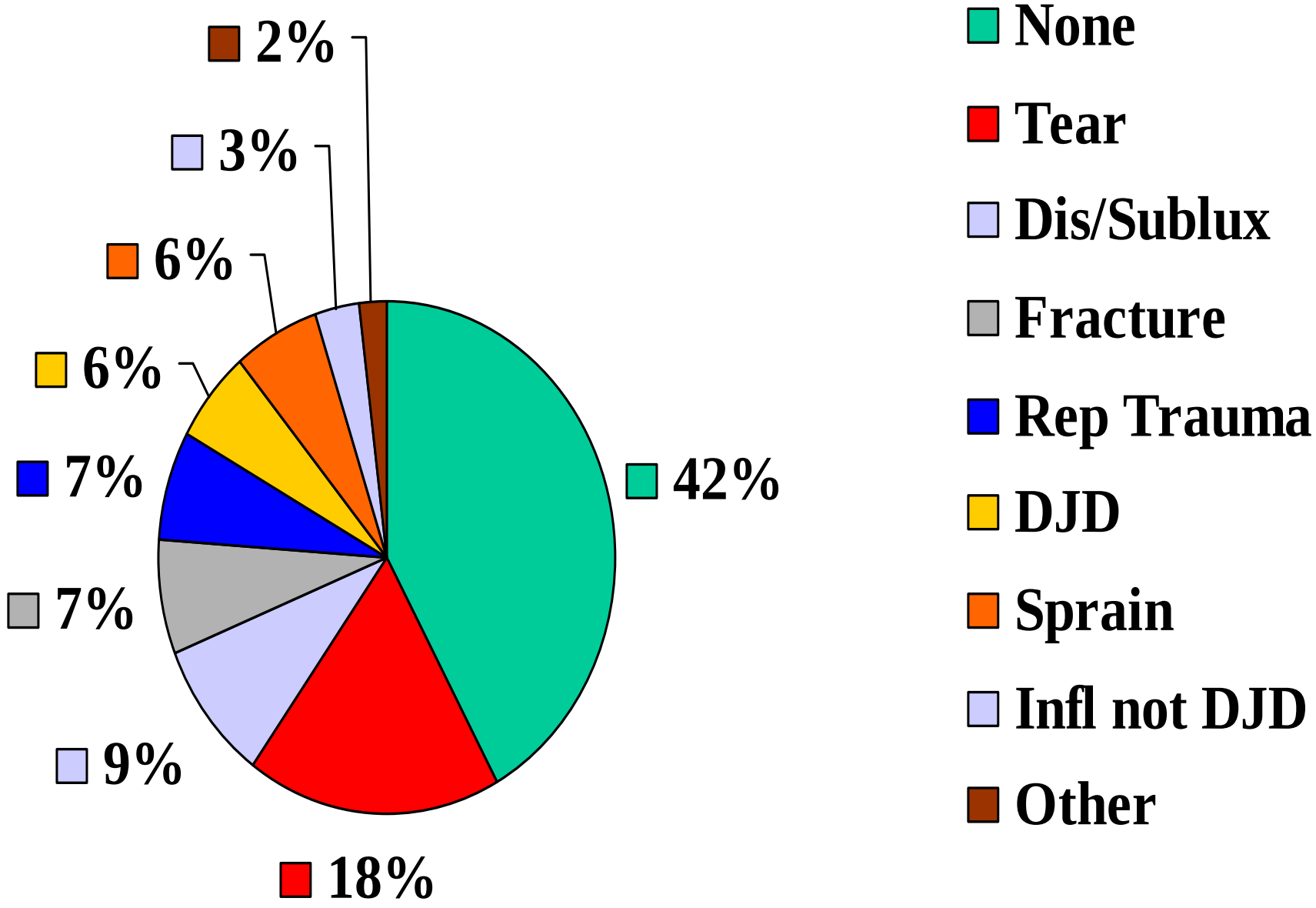
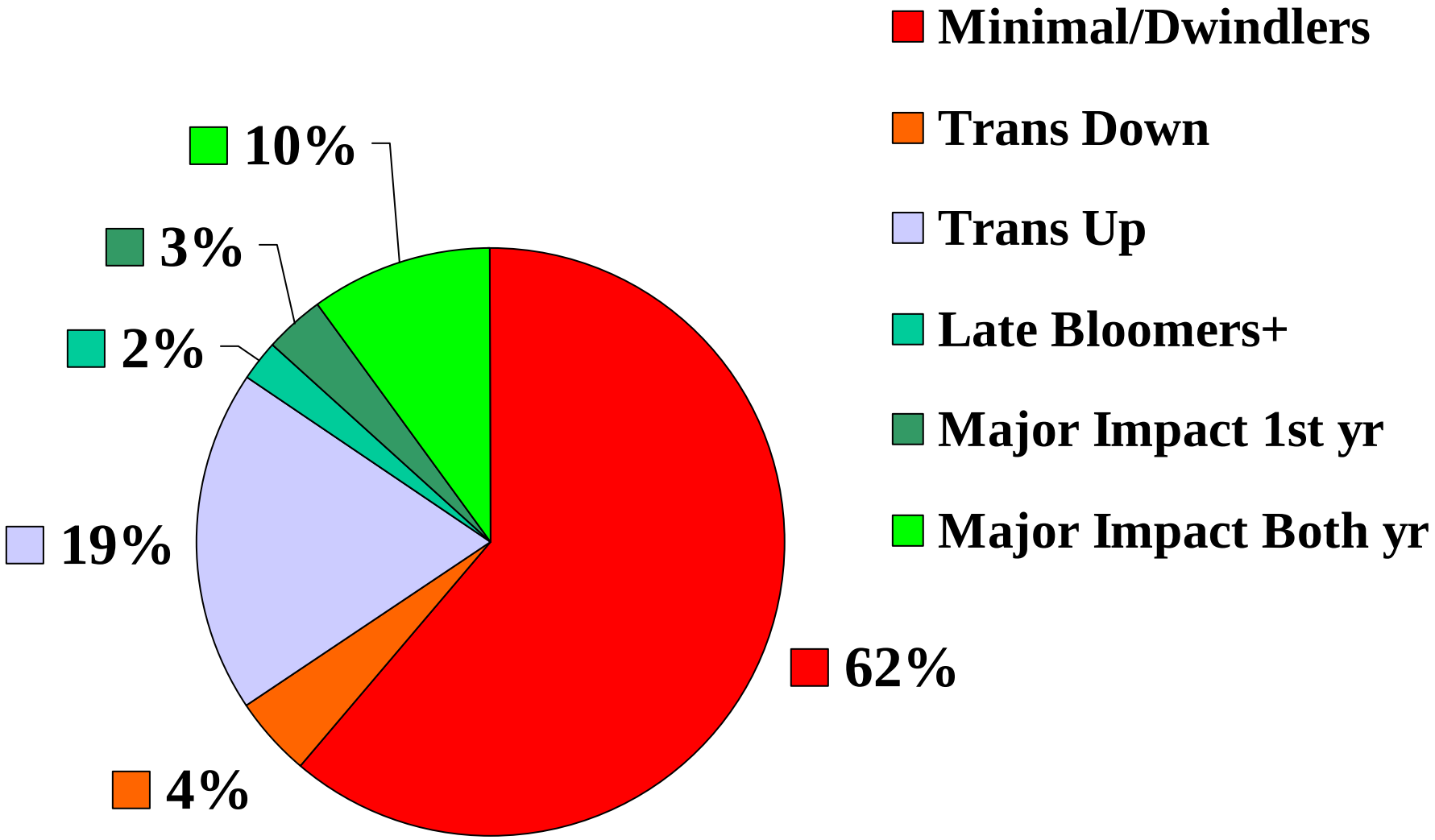
37
BMI Silhouettes
< 25

MOST RECENT INJURY DIAGNOSIS



QUALITY? OF PARTICIPATION OVER BOTH YEARS



The Seated, Routine-Office Posture Is Not Optimal For Predicting 24-Hr Ambulatory Blood Pressure

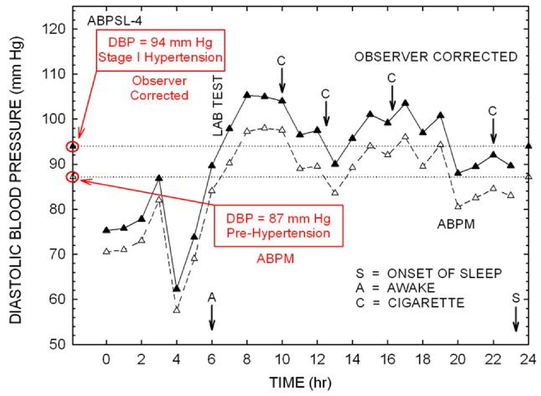
V. Patteson Lombardi[1], Dennis R. Taaffe[2], Marc Kaltenhauser[3], & Donald L. Pate[4]. University of Oregon, Departments of Biology[1] & Human Physiology[3] & Institute of Neuroscience[4], Eugene, OR USA 97403 & School of Human Movement Studies[2], The University of Queensland, St. Lucia, QLD, Australia 4072

AMERICAN SOCIETY OF HYPERTENSION
24th ANNUAL SCIENTIFIC MEETING & EXPOSITION
MAY 6-9, 2009, SAN FRANCISCO, CA, USA 94103

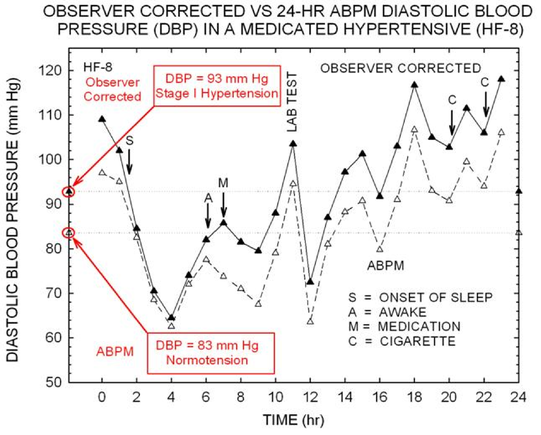
BACKGROUND Zachariah, Sheps and Moore (*Int J Cardiol*, 1990, 28, 353-60) examined relationships among 24-hr ambulatory blood pressure monitor (ABPM) and clinic postural measurements, but did not correct for ABPM inaccuracies. We have demonstrated that an AAMI and FDA approved ABPM can underestimate pressures and that unless ABPM field values are corrected, up to 90% of patients can be misdiagnosed and potentially mismanaged. The question remains as to whether there exists a best posture for measuring office blood pressure and how postural measurements relate to corrected ABPM values.

METHODS We developed a protocol with postural challenges to establish corrections factors specific for each subject, posture and arm position prior to 24-hr ABPM field testing. We assessed routine office systolic (SBP) and diastolic (DBP) pressures, then exposed suspected hypertensives (HTN, n=9) and primary alcohol-dependents (1⁰ ETOH, n=11) to a series of lab measurements involving postural challenges. Two observers using a mercury column and teaching stethoscope assessed same arm pressures simultaneously with ABPMs.

OBSERVER CORRECTED VS 24-HR ABPM DIASTOLIC BLOOD PRESSURE (DBP) IN A PRIMARY ALCOHOL DEPENDENT (ABPSL-4)



OBSERVER CORRECTED VS 24-HR ABPM DIASTOLIC BLOOD PRESSURE (DBP) IN A MEDICATED HYPERTENSIVE (HF-8)



Best Lab/Clinic Postures, Arm Positions & Equations for Predicting ABPM 24-hr, Awake & Sleep Blood Pressures in Primary Alcohol-Dependents (1⁰ ETOH) & Hypertensives (HTN)

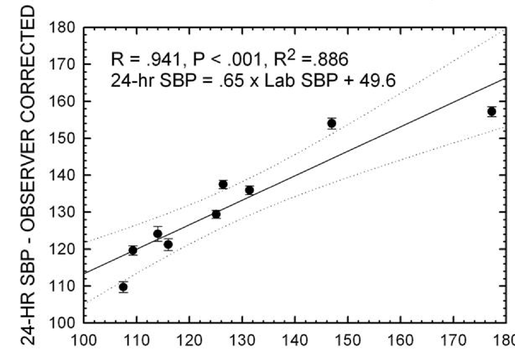
Group	Pressure	24-hr	Awake	Sleep
1⁰ ETOH	SBP	Supine Phlebostatic R=.941, P<.001, R^2=.886 *24-hrBP=.65LabBP+49.6*	Seated Relaxed* R=.921, P<.001, R^2=.848 *AwakeBP=.85LabBP+30.1*	Supine Phlebostatic R=.864, P=.001, R^2=.746 *SleepBP=.79LabBP+12.7*
	DBP	Supine Phlebostatic R=.732, P=.010, R^2=.536 *24-hrBP=.49LabBP+45.5*	Supine Phlebostatic R=.670, P=.024, R^2=.449 *AwakeBP=.39LabBP+57.1*	Supine Phlebostatic R=.672, P=.023, R^2=.452 *SleepBP=.94LabBP-7.5*
HTN	SBP	Seated Relaxed R=.752, P=.019, R^2=.566 *24-hrBP=.47LabBP+73.9*	NS	NS
	DBP	Standing Relaxed R=.914, P=.001, R^2=.835 *24-hrBP=.61LabBP+33.0*	Standing Relaxed R=.828, P=.006, R^2=.686 *AwakeBP=.50LabBP+48.7*	Standing Relaxed R=.761, P=.017, R^2=.579 *SleepBP=.51LabBP+25.3*

*NB: For 1⁰ETOH, in predicting ***Awake*** ABPM, Supine Phlebostatic (R=.920, P<.001, R^2=.846; *AwakeBP=.61LabBP+58.3*) was a close second behind the Seated Relaxed position.

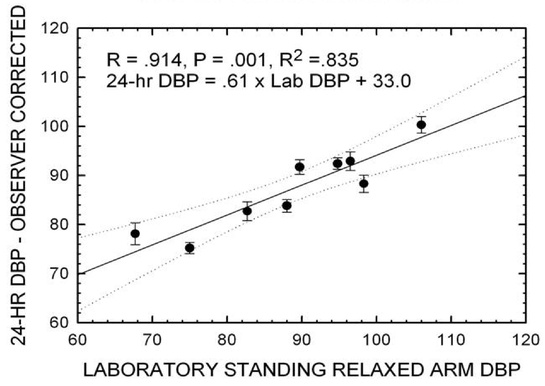
Comparing Posture & Arm Position for Lab Measurements with 24-hr, Awake & Sleep Systolic (SBP) and Diastolic (DBP) Blood Pressures Obtained by Ambulatory Blood Pressure Monitoring (ABPM) In Medicated & Non-Medicated Hypertensives

		SBP from ABPM						DBP from ABPM					
		24-hr		Awake		Sleep		24-hr		Awake		Sleep	
	Lab Position	R	R^2	R	R^2	R	R^2	R	R^2	R	R^2	R	R^2
	Supine Phlebostatic	.671*	.450	.516	.266	.555	.308	.762*	.581	.652	.425	.694*	.481
		P=.048		P=.155 NS		P=.121 NS		P=.017		P=.057 NS		P=.038	
	Seated Phlebostatic	.680*	.462	.426	.181	.625	.391	.695*	.483	.542	.294	.681*	.464
		P=.044		P=.253 NS		P=.072 NS		P=.038		P=.132 NS		P=.043	
✓	Seated Relaxed	.752*	.566	.578	.334	.520	.270	.667*	.445	.760*	.578	.403	.162
		P=.019		P=.103 NS		P=.151 NS		P=.050		P=.017		P=.282 NS	
	Standing Phlebostatic	.327	.107	.174	.030	.400	.160	.800*	.640	.724*	.524	.734*	.539
		P=.390 NS		P=.655 NS		P=.286 NS		P=.010		P=.027		P=.024	
✓	Standing Relaxed	.489	.239	.257	.066	.582	.339	.914*	.835	.828*	.686	.761*	.579
		P=.181 NS		P=.505 NS		P=.100 NS		P=.001		P=.006		P=.017	
	Overall	.581	.338	.584	.341	.418	.175	.866*	.750	.768*	.590	.762*	.581
		P=.101 NS		P=.099 NS		P=.263 NS		P=.003		P=.016		P=.017	

AVERAGE 24-HR SYSTOLIC BLOOD PRESSURE (SBP) vs. LABORATORY SUPINE PHLEBOSTATIC ARM SBP IN PRIMARY ALCOHOL DEPENDENTS (1⁰ ETOH)



AVERAGE 24-HR DIASTOLIC BLOOD PRESSURE (DBP) vs. LABORATORY STANDING RELAXED ARM DBP IN SUSPECTED HYPERTENSIVES



RESULTS For all subjects (n=20), compared to standard, routine office pressures, comprehensive postural measurements were more predictive of ABPM 24-hr and awake pressures, improving the prediction of ABPM SBP by approximately 23-26%, and ABPM DBP by 17-23%. For 1⁰ ETOH, supine phlebostatic arm SBP was the most predictive of 24-hr and sleep SBP, while together with seated relaxed arm SBP was a powerful awake SBP predictor. For HTN, standing relaxed arm DBP was the most powerful predictor of 24-hr, awake, and sleep DBP.

CONCLUSIONS Our results, in a small group of carefully studied subjects, indicate that standard routine office measurements in the seated phlebostatic position, are less than optimal for predicting field pressures obtained from an ABPM. Measurements at the extreme ends of the postural challenge continuum – from supine phlebostatic to standing relaxed arm positions – appear to be the most predictive. This may explain at least partly why ABPM values are slightly more correlated with target-organ damage, CVD risk and CVD mortality compared to routine office seated pressures obtained at a single point in time. While certainly more research is warranted, we encourage all practitioners to employ postural challenges in their routine assessments of blood pressure in attempt to envision a more comprehensive pressure profile. We also suggest that all ABPM values be corrected based on differences observed in the clinic prior to field testing, particularly for DBP.

Approved Ambulatory Blood Pressure Monitor Underestimates Diastolic Pressure & Misclassifies Alcohol-Dependent Patients

V. Patteson Lombardi[1], Marc Kaltenhauser[2], Donald L. Pate[3] & Dennis R. Taaffe[4]. University of Oregon, Departments of Biology[1] & Human Physiology[2] & Institute of Neuroscience[3], Eugene, OR USA 97403 & School of Human Movement Studies[4], The University of Queensland, St. Lucia, QLD, Australia 4072

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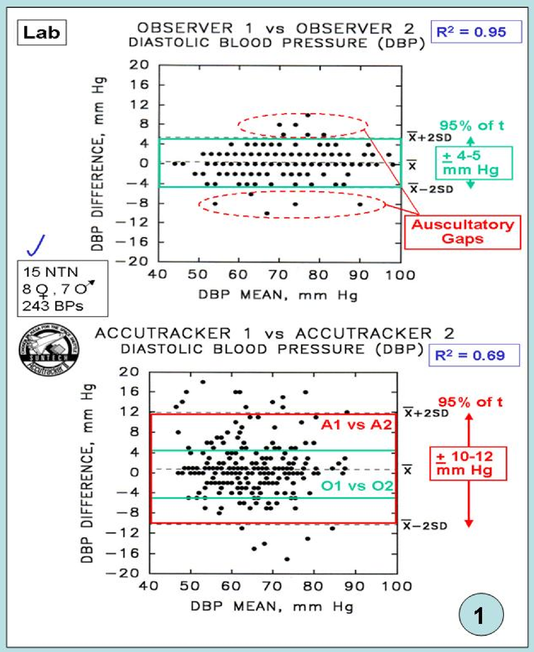
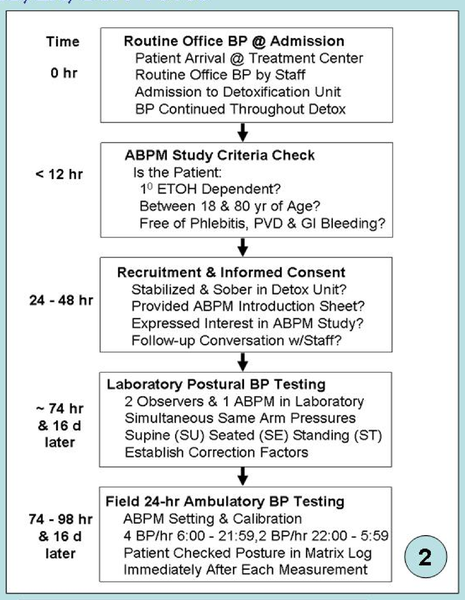
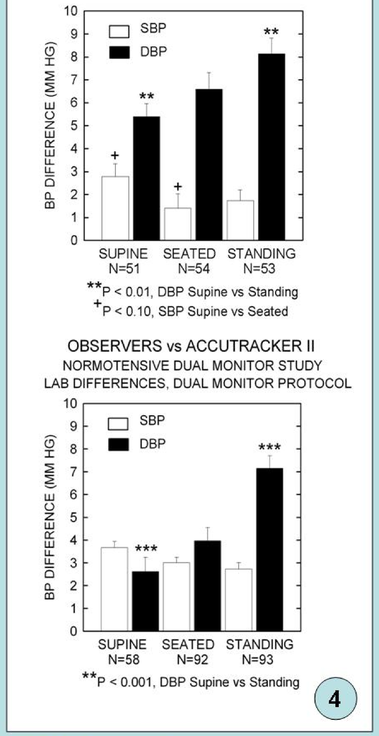


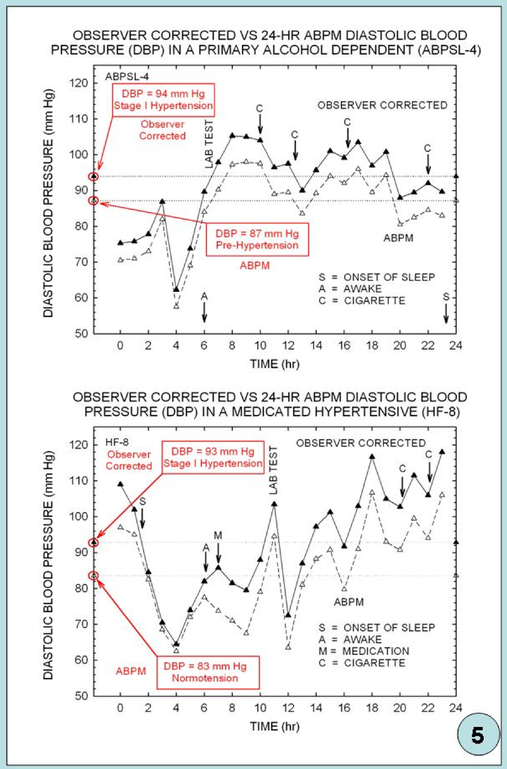


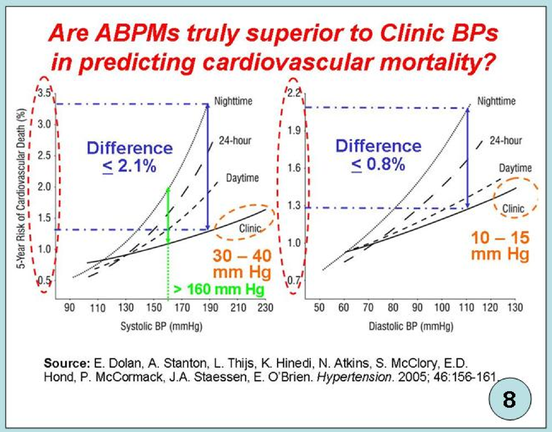
CLINICALLY SIGNIFICANT DIFFERENCES IN ABPM & OBSERVER-CORRECTED NHLBI (1997, 2003) CLASSIFICATIONS OF LABORATORY SYSTOLIC (SBP) & DIASTOLIC (DBP) PRESSURES IN 11 PRIMARY ALCOHOL-DEPENDENTS

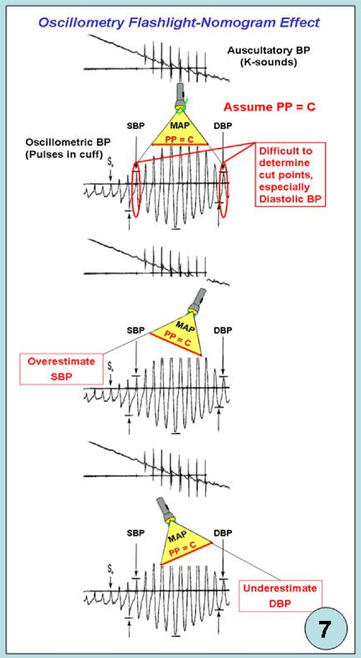
Patient	BP Source	SBP	NHLBI Class		DBP	NHLBI Class	
1 ♂ 37 yr	Observers	129.7	Normal	✔	87.5	Pre HTN	⊘
	ABPM	127.7	Normal		80.8	Normal	
	Δ	2.0			6.7		
2 ♂ 37 yr	Observers	128.4	Normal	✔	89.1	Pre HTN	⊘
	ABPM	124.5	Normal		80.6	Normal	
	Δ	3.9			8.5		
3 ♂ 49 yr	Observers	155.7	Stage I HTN	✔	92.9	Stage I HTN	⊘
	ABPM	151.2	Stage I HTN		88.4	Pre HTN	
	Δ	4.5			4.5		
4 ♂ 32 yr	Observers	121.8	Normal	✔	86.6	Pre HTN	⊘
	ABPM	120.2	Normal		79.9	Opt Normal	
	Δ	1.6			6.7		
5 ♀ 29 yr	Observers	104.5	Optimal BP	✔	80.3	Normal	⊘
	ABPM	103.8	Optimal BP		71.2	Optimal BP	
	Δ	0.7			9.1		
6 ♂ 31 yr	Observers	119.3	Optimal BP	✔	87.6	Pre HTN	⊘
	ABPM	117.9	Optimal BP		79.9	Optimal BP	
	Δ	1.4			7.7		
7 ♂ 39 yr	Observers	138.7	Pre HTN	✔	91.0	Stage I HTN	⊘
	ABPM	138.2	Pre HTN		84.7	Normal	
	Δ	0.5			6.3		
8 ♀ 35 yr	Observers	114.3	Optimal BP	✔	80.4	Normal	⊘
	ABPM	110.0	Optimal BP		68.4	Optimal BP	
	Δ	4.3			12.0		
9 ♂ 30 yr	Observers	112.5	Optimal BP	✔	81.9	Normal	⊘
	ABPM	109.8	Optimal BP		73.5	Optimal BP	
	Δ	2.7			8.4		
10 ♂ 43 yr	Observers	120.8	Normal	✔	92.6	Stage I HTN	⊘
	ABPM	120.4	Normal		86.4	Pre HTN	
	Δ	0.4			6.1		
11 ♂ 59 yr	Observers	165.1	Stage II HTN	✔	98.8	Stage I HTN	✔
	ABPM	165.1	Stage II HTN		97.1	Stage I HTN	
	Δ	0.0			1.7		

3









BACKGROUND (1) We demonstrated in normotensives & hypertensives that an AAMI & FDA approved ambulatory blood pressure monitor (ABPM) was highly variable in assessing diastolic pressure (DBP) & had lower levels of agreement compared to trained observers using auscultation & an Hg column.

METHODS (2) To determine if our results could be applied to special patients in a controlled clinical setting, we assessed routine office multi-postural lab & 24-hr pressures in 11 primary alcohol dependents undergoing detoxification & abstinence. We hypothesized that the approved ABPM would underestimate DBP leading to misclassification of patients according to NHLBI guidelines.

RESULTS (3) For 10 of 11 patients in the lab, the ABPM incorrectly assessed DBP based on NHLBI classifications. (4) The stepwise underestimation of lab DBP from supine, to seated to standing, was identical to previous findings. (5) (6) For DBP values from 24-hr tests, ABPM underestimated the observers' NHLBI DBP classification by at least 1 category 56% of the time, and misclassified patients as normotensive when prehypertensive, prehypertensive when hypertensive & optimally normotensive when normotensive.

CONCLUSIONS These results confirm conclusively that an approved auscultatory ABPM underestimates DBP & leads to patient misclassification. (7) Oscillometric ABPMs are perceived as being more robust, yet they are susceptible to underestimation & misclassification due to the flashlight effect, 2nd generation indirect equation-based estimations, & basic hemodynamic laws. (8) Despite a 10- to 30-fold measurement frequency advantage, ABPMs are only marginally (1-2%) better than clinic BP in predicting cardiovascular death & only for nighttime SBP (>160 mm Hg), when subjects are nonambulatory. Ambulatory DBP is < ½ as effective as SBP in predictability, supporting our finding of inaccurate diastolic assessment. The highest ABPM DBPs are 10-15 mm Hg lower than the highest clinic DBPs implying ABPM DBP underestimation above & beyond the white coat effect. To ensure accuracy, reliability, realistic diurnal views, proper patient management & results interpretation, ABPM data points must be corrected based on postural challenges prior to field tests. All US & International Protocols (AAMI, BHS, ESH IP) for validating ABPMs should require multi-postural tests. Intensive study of basic hemodynamics & auscultatory & oscillometric relationships will foster the design of more accurate & reliable monitors.

CLINICALLY SIGNIFICANT DIFFERENCES IN ABPM & OBSERVER-CORRECTED NHLBI (1997, 2003) CLASSIFICATIONS OF 1275 ABPM FIELD SYSTOLIC (SBP) & DIASTOLIC (DBP) PRESSURES IN 11 PRIMARY ALCOHOL-DEPENDENTS

ABPM vs Observer NHLBI Classification	%SBP Values	%DBP Values
+1 *ABPM 1 Category Above Observers* (eg ABPM indicates Prehypertension, Observers Normotension)	3%	1%
+0 *ABPM Identical Category as Observers* (eg Both ABPM & Observers indicate Normotension)	85%	44%
⊘ -1 *ABPM 1 Category Below Observers* (eg ABPM indicates Normotension, Observers Prehypertension)	12%	~40%
⊘ -2 *ABPM 2 Categories Below Observers* (eg ABPM indicates Normotension, Observers STAGE I Hypertension)	0%	15%
⊘ -3 *ABPM 3 Categories Below Observers* (eg ABPM indicates Normotension, Observers STAGE II Hypertension)	0%	~1%
		56%

6

A Postural-Adjustment 24-hr Ambulatory Blood Pressure Monitor (pABPM) for Improving Accuracy & Reliability?

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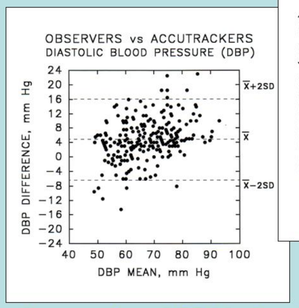
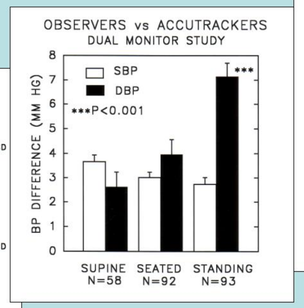
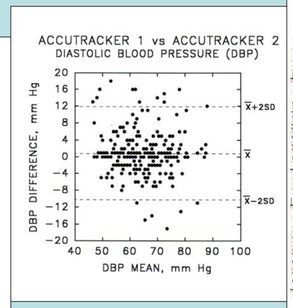
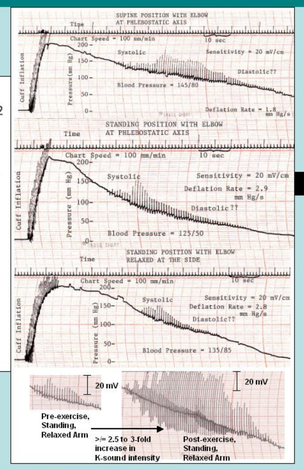
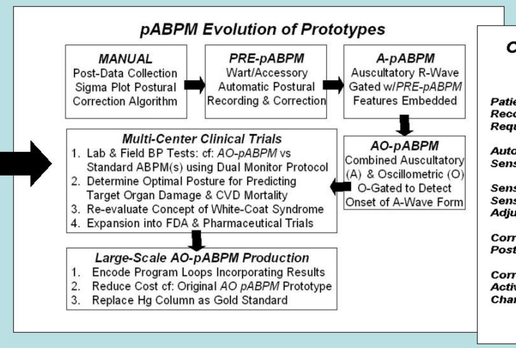








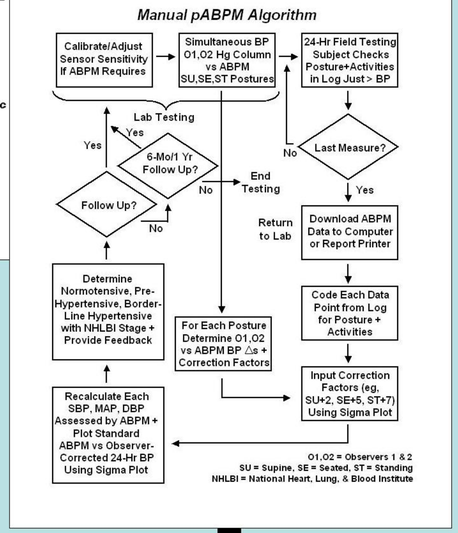
A popular ABPM significantly and variably underestimates diastolic blood pressure (DBP) relative to two trained observers using a mercury column to assess same arm pressures simultaneously. We have demonstrated this in normotensives, medicated and nonmedicated hypertensives, and primary alcohol-dependent patients. Underestimations differ significantly according to posture and the highest variability is demonstrated in transitional measurements, those that occur after a change in body or arm position. Two identical make ABPMs measuring same arm pressures simultaneously have a poor (R^2 < 52%) level of agreement. Our theory that ABPM accuracy and reliability problems were linked to Korotkoff sound intensity variations with posture and activity was supported by polygraph data.

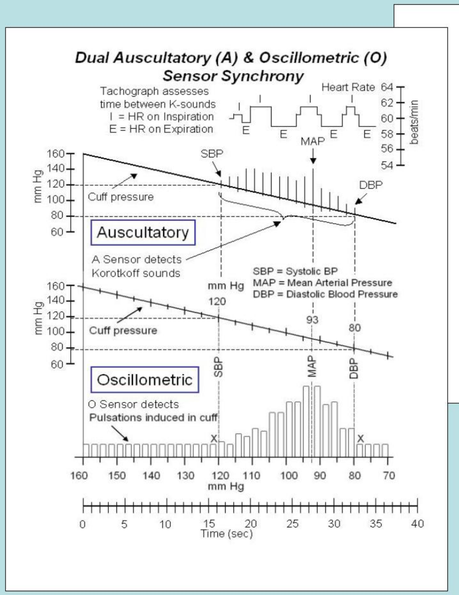


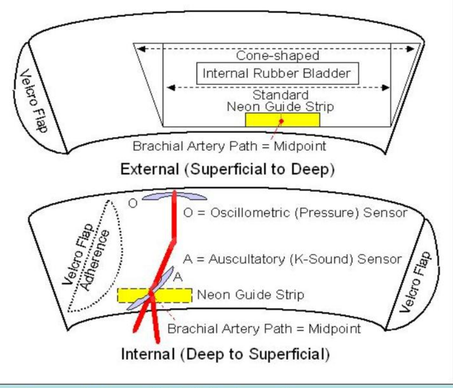
Comparing Standard ABPMs vs pABPM Prototypes

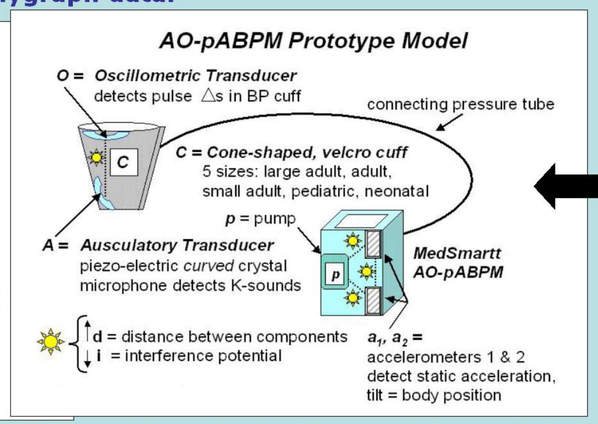
	Standard	Manual	PRE-pABPM	A-pABPM	AO-pABPM
Patient Hand-Recording Required?	No	Yes	No	No	No
Automatically Senses Posture?	No	No	Yes	Yes	Yes
Sensor/Transducer Sensitivity Adjustment?	Static/ 1 Step Behind	Static/ 1 Step Behind	Dynamic	Dynamic	Dynamic
Corrects BP for Postural Changes?	No	Yes	Yes	Yes	Yes
Corrects BP for Activity Level Changes?	No	No	No	No	Yes

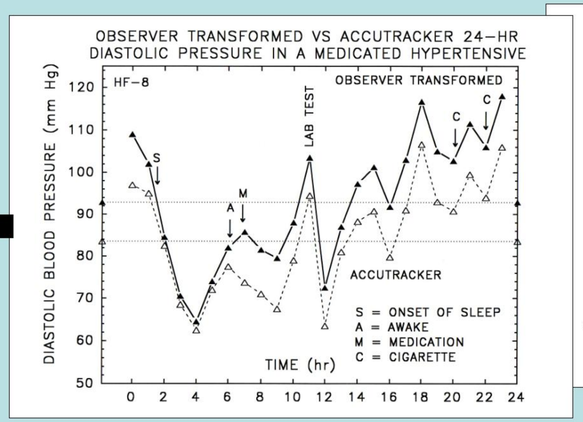
Since current ABPMs do not determine subject posture and activity level, it is likely that all ABPMs (without regard for make or model) are at best 1-step behind in sensor sensitivity adjustments, and thus prone to error and high variability. We sought to develop a postural- and activity-adjusting ABPM (pABPM) and initially envisioned four prototype stages, the first of which we have established. This Manual pABPM involves observers assessing same arm pressures simultaneously with any model ABPM, as subjects assume multiple postures in the laboratory prior to field studies. During 24-hr testing, subjects record posture and activities immediately after each measurement, and later each data point is adjusted based on original laboratory differences.

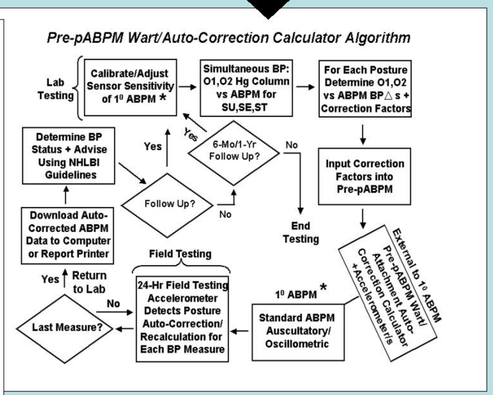












The AO-pABPM is the most sophisticated model in the evolution of the pABPM prototypes. Like the accessory/wart Pre-pABPM, the AO-model can assess a subject's posture. However, unique to this model are: (1) embedding of our Dual Monitor Protocol (DMP) into a single unit, (2) use of synchronized oscillometric and auscultatory sensors which compare and contrast measurements, and (3) use of curved sensors which traverse the brachial artery and are fitted to the natural contour of the arm.

The second generation prototype is the Pre-pABPM wart/auto-correction calculator, which theoretically can be attached to any currently available auscultatory or oscillometric ABPM. Unlike our Manual pABPM prototype, the Pre-pABPM uses accelerometers to assess body position & automatically recalculates each BP measurement according to previously established postural correction factors. The graph illustrates BP data point adjustments similar to those made by the Manual pABPM and the Pre-pABPM accessory, auto-correction prototype.