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**Correlation of Static and Dynamic Balance Indices to
Injury History,
Performance Criteria,
and
Physical Findings
in
595 Elite College Football Players**

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Balance Assessment Howaid, Cawley, et al

Abstract

This investigation reports the development and validation of an instrumented unstable platform designed to quantify static and dynamic balance indices. In the first series of tests, static balance indices were investigated in a group of 293 elite college football players. In the second series, dynamic balance indices were evaluated in a group of 302 elite college football players. For both groups, balance indices were correlated with injury history in the lower extremity, physical exam findings, and functional performance data. For the static balance group, it was noted that limb dominance appears to be a predictor of ultimate static balance performance in non-injured subjects. In subjects with a history of lower extremity injury, a trend towards skewing toward the non-involved limb was noted. Analysis of dynamic balance data demonstrated significant differences between injured and non-injured groups. For both static and dynamic balance groups, there was a high correlation of balance results with scores on the 40 yard shuttle run. It appears that the instrumented unstable balance platform is a sensitive discriminator of neuromuscular deficits resulting from lower extremity injury.

Balance Assessment Howara, Cawley, et al

Introduction

The primary objective in the rehabilitation following injury to the lower extremity is to safely promote healing of the affected tissue while restoring normal function to the affected limb. Re-establishing normal function following lower extremity injury is comprised of the restoration of joint/fracture stability, the re-establishment of normal range of motion (ROM), muscular strength and endurance, plus the complete re-training of the neurosensory or motor control system. Incomplete restoration of normal neurosensory pathways prevents the athlete/patient from returning to pre-injury levels of function, despite the restoration of adequate stability, ROM, strength and endurance of the lower extremity. Adequate motor control aptitude is thought to be the final element required to complete the rehabilitation process following injury to the lower extremity. Ironically, motor control is the only factor that has not been specifically defined, adequately treated, or objectively assessed.

The future of motor control in surgical and clinical application is rapidly expanding with the expanded research into its role in protective reflexes. Over the past two to three years there has been a heightened awareness of the role of proprioceptive/motor control training and assessment following injury or surgery to the lower extremity.

1.4.7.11.12,16.17.19.20,23.27.29.31,34.35,39,40 It is generally believed that injury to the joint and surrounding structures results in altered proprioceptive feedback that negatively affects motor control. The implementation of early neurosensory retraining has been advocated to minimize neuromuscular atrophy and to promote the safe return to full function. 19.23,29.32

Balance Assessment HowarJ, Cawley, et al

Proprioception, kinesthesia, and motor control.

Proprioception is often confused in the literature with closely related topics such as kinesthesia, reflexive muscle splinting, postural balance and motor control.

Proprioception is defined as the cumulative neural input to the central nervous system (CNS) from the mechanoreceptors in the joint capsules, ligaments, muscles, tendons, and skin. 17.39 It has traditionally been measured by two techniques: either the threshold of the detection of passive motion or the ability to reproduce passive positioning. 24.18,23 While the most sensitive test of joint proprioception is the threshold to detection of passive movement, this is not a functionally relevant or clinically applicable test; and thus its significance must be questioned.

Kinesthesia, on the other hand, is the conscious awareness of joint position and movement resulting from afferent neural input received in the CNS.15 Incoming proprioceptive input is integrated with afferent signals from the vision and vestibular systems in the CNS to monitor limb and body position relative to the center of gravity (COG).1 Neuromuscular control, also termed “motor control”, integrates the proprioceptive, kinesthetic, and somatosensory input with efferent muscular output, utilizing a servomechanism called a biofeedback loop, in producing purposeful coordinated movement. These neuromuscular pathways are stimulated, facilitated, maintained, and enhanced through functional movement and exercise.

Balance Assessment Howard, Cawley, et al

Balance therapy.

Balance is defined as the state of bodily equilibrium.23 Postural balance is the ability to maintain the body’s COG over the base of support provided by the feet. For a body to remain upright in balance against gravity, many fine orchestrated neuromuscular adjustments must be made. The motor control of the body’s COG during postural balance is also governed by a biofeedback loop. The activation of appropriate muscular response patterns are directly influenced by the complex interaction and integration of all pertinent afferent neural input at the level of the CNS.39 It is believed that altered proprioceptive input, due to injury of the lower extremity, will adversely influence the neuromuscular control of postural balance. Adequate postural balance is required before effective and efficient locomotion can be achieved. Balance training or therapy stimulates an inhibited neuromuscular system by imposing functional demands.

The utilization of balance and other functional proprioceptive activities in the rehabilitation following lower extremity injury is well documented. 5.12.19 However, reported rehabilitation protocols do not traditionally initiate proprioceptive balance training until adequate ROM, strength, and, endurance is achieved; usually weeks after therapy has started. Clinical observations, anecdotal evidence, and initial prospective data, as seen by the authors, suggests that immediate balance activities can have a profound effect upon early return of neuromuscular function.

Balance Assessment Howard, Cawley, et al

Purpose.

Until recently, there has been no reproducible or readily accessible means of documenting neurosensory deficit in the lower extremity and no reliable means of quantifying the effects of balance and neurosensory specific therapies on recovery rate and outcome. The purpose of this investigation was to validate the use of an instrumented unstable platform in documentation and assessment of normal balance aptitude in a large athletic population. A further aim of this investigation was to compare balance aptitude scores in a group of elite college football players to their athletic performance, history of lower extremity injury, and objective physical findings upon orthopaedic examination of the lower extremity.

Discussion

The re-establishment of neuromuscular control and proprioceptive aptitude is imperative following injury or surgery to the lower extremity. The awareness of neuromuscular dysfunction following injury to the lower extremity should stimulate the practitioner to specifically design a neuromuscular retraining program that meets the specific functional needs of the involved joint. Incomplete neuromuscular rehabilitation affects athletic performance and can lead to re-injury. The neurosensory and proprioceptive input from the lower extremities is very important in overall function and balance. The use of an objective, reliable, relatively inexpensive and easy method to assess proprioception as it relates to overall balance and function following lower extremity injury would greatly enhance the determination for a safe return to play.

As a measurement of proprioception, several studies have examined the joint position sense at the hip, knee and ankle joints. 2,3,5,6,9.,15.18,23 Barrack et al suggested that a decrease in joint position sense may increase the chance of acute or chronic injury as a result of inadequate protective reflexes In 1988.2 The same authors showed that a complete rupture of the anterior cruciate ligament had increased the threshold of detection of joint position sense by loss of afferent input. However, it is quite difficult to extrapolate objective test results of proprioceptive ability utilizing position sense measurements to overall functional balance aptitude. Testing of static and dynamic standing balance is more specific in assessing overall functional neuromuscular capabilities. No balance test is fully capable of isolating proprioception, but is more functional in assessing integrated neuromuscular control. It must be pointed out that balance aptitude is also affected by the visual feedback, vestibular acuity, and neurological deficit. These factors must be realized and then controlled for the accurate assessment of balance ability.

The review of literature shows few studies about balance testing in the fields of orthopedics and sports medicine. 46.11.16,20.29.30,40 Several studies have been done in the fields of neurology and gerontology. 6.18.25,26.33,36 Balance testing, or stabilometry as described by Tropp et al is an objective method for the study of postural control. It is a quantification of a modified Romberg test. In 1965, Freeman, a pioneer in the assessment of balance in the field of orthopedic medicine, used the Romberg test to compare single limb stance balance performance between involved and uninvolved lower extremities. 13,14 There were no quantified results but his conclusions were that there was significant differences between groups. His findings were supported by more recent studies. Most studies tested single stance balance but this may be insufficient to draw conclusion about overall balance and function. 10,15,25,37 Ekdahl et al, via the use of a stable computerized force platform, studied balance in healthy subjects as it relates to age and sex. They noted that there is no adequate consensus on how standing balance should be defined. They also suggested that further studies should consider the value of the functional and force platform tests together in diagnosing well known and defined lesions.

More recently, Pitman ET al showed direct evidence of proprioceptive function of the anterior cruciate ligament. 34 Kennedy ET al presented the rich innervation of the soft tissue of the knee. 26 However, Klein et al quoting previous work by Kennedy, reported that the role of proprioception of the mechanoreceptors in the ACL had yet to be established. 27 At the same time, Branch et al found that when the neuromuscular system was intact, balance was not affected by impaired joint position sense and absent cutaneous sensation.⁷ This would corroborate speculations of Harter et al and Dvir et al that sensory feedback may be more controlled by Golgi tendon organs and muscle spindles than by mechanoreceptors located in the joint capsule and articular surfaces. 9, 21 it appears that the sole study of joint position sense may not be sufficient to determine levels of proprioception as it relates to overall function following a lower extremity injury.

Horak suggested that sophisticated equipment such as computerized force platforms and motion analysis machines would enable therapists to more accurately evaluate balance and overall function. 24 Usage of force platforms with computer interface is expensive and impractical in the clinical setting. Mechiling adapted a practical clinical assessment tool called a variable resistance balance board but it had a single axis of pivot in the frontal plane and therefore had limited application. 3° To date, several other systems have been developed to obtain more detailed quantitative measurements (Wright's ataxiometer, stationary stable force platforms, tilting platforms) with regards to balance assessment, however are either clinically impractical or to

Balance Assessment Howarc1. Cawley, et al

Expensive. 8, 10,11,15,16,23,31,39

Many authors, starting with Freeman, have described the benefits of balance and proprioceptive training following lower extremity injury. 13 Balance therapy, it is reported, stimulates an inhibited neuromuscular system by imposing functional demands. 19 Testing of balance, it would seem, can have a vital impact on establishing baseline data and monitoring progress during rehabilitation following rehabilitation of a lower extremity injury. In an attempt to correlate balance performance to specific lower extremity injuries, an instrumented unstable platform was utilized in this study. One of the main purposes of this investigation was to evaluate the feasibility of utilizing an instrumented balance system in the assessment of balance capabilities. The verification of the algorithm to compensate for body weight was the initial step in the validation of the system. In theory, a person of greater weight would have a more difficult time of stabilizing the platform. In other words, a heavier person shifting half of their body weight from the center would have a more difficult time balancing on a totally unstable platform than a lighter person shifting the same percent of their weight. This was evaluated in two ways. First by testing subjects at a given difficulty level and recording their balance indices, and then adding dead weight and re-testing at the appropriate change in inflation to accommodate the change in weight per the algorithm, their re-test balance index should not change. This is based upon the fact that their inherent balancing aptitude is not different, irregardless of body weight. The test-retest data from the 10 normal subjects showed no significant difference for 0#, 25#, and 50# test conditions. Secondly, if the entire population in the study group showed a strong positive correlation with SBI and body weight ($r=0.063$), the algorithm would be invalid. It has also been asserted that subject height influences balance aptitude due to increased body sway. In this series of subjects, height had no relationship with balancing ability.

After looking at the test-retest data of the 20 normal volunteers and the entire study group, it is apparent that, with the exception of the first test in the series, balance indices are quite reproducible. The first test seems to be a learning curve. Of clinical importance, testing of balance aptitude should include ample practice and familiarization on the device before acquiring data for comparative analysis.

The testing protocol required the subjects to stand with their feet equidistant apart (10 inches), and comfortably situated forward to back. Further evaluation of foot placement (front to back) is necessary. The subjects were also instructed to bend the knees (approximately 20-30°). This specific requirement was instituted to evaluate the entire lower extremity balance aptitude. If the tests were conducted with straight upright hips, knees, and ankles, the test would mainly be evaluating ankle/calf posturing. Also during the testing, the athletes were instructed to look straight ahead at the computer screen or wall, and focus on the target cursor or a point on the wall 3 feet away. This requirement helped control, not eliminate, vestibular and visual feedback. The subjects also folded their arms across their chest, minimizing balance control by ballistic arm movement. The double leg balance test was chosen as one in a series of evaluations of balance indices.

Further tests will include single leg stance balance testing. These tests will also be evaluated and correlated to performance and injury in the future. Upon analysis of the normative data for all test subjects, one can see that the frequency of balance index scores and Right-Left Ratios fall relatively evenly in relationship to a normal Gaussian curve. The balance index frequency distribution demonstrates some skewness (1.12) and some kurtosis (2.58). Whereas the RLR frequency distribution shows 0.12 skewness and 0.26 of kurtosis. These findings may be attributed to the fact that the total population includes some subjects that are or have been injured which will affect their balance index and RLR data. A much larger subject population would be of benefit here. Analysis of frequency distributions of sub-groups was not carried out due to relatively smaller sample sizes.

Analysis of the mean SB I's of the various individual position sub-groups showed no statistically significant differences within the groups. However, of clinical importance, is the fact that sub-groups which required more balance aptitude, had lower overall SBI's. In other words, there were notable differences between the "skill" positions and the "non-skill" positions. Analysis of the mean DBI's of the various individual position sub-groups showed no statistically significant difference within the groups. This may be due to the fact that the test group is fairly homogeneous, i.e. young, health males of the same sport. After position ranking by DBI, there was observable differences between the "skill" positions and the "non-skill" positions. Having knowledge of approximate normative balance capabilities for specific sports could have significant implication when evaluating injured athletes balance aptitudes. Further testing of normal subjects, male and female, with varying activity levels in a multitude of sporting activities, is warranted. This would help establish more extensive normative data base in which to reference during the rehabilitation of lower extremity injuries for particular sports. Statistical analysis of the gross DBI scores of the elite college football players by history of lower extremity injury and by present lower extremity orthopaedic findings showed significant differences among the players that had no orthopaedic history or findings with the group of players that had significant physical findings and were unable to participate in workouts. These findings corroborate evidence from other researchers that following a knee injury, proprioception correlates better with patient satisfaction than do knee scores, stability testing, and ability to return to sports. 3,6,213 More data is required to further evaluate this relationship. Perhaps a query of the DBI of subjects with a history of lower extremity injury and perceived functional capacity would delineate this relationship more.

Upon evaluating the data for subjects with no injury history and negative findings on physical examination compare to percent right - left differences, it was noted that the Majority of subjects tended to skew or tilt toward the right side or positive X axis during the static balance test. Since the objective of the static balance test is to center the platform and hold it in a neutral position for the duration of the test, the ideal result would be to have a right - left difference of zero. In other words, equivalent time would be spent in both the positive (right) and negative (left) segments of the X axis. Non-injured subjects spent approximately 25% of the test duration tilted to the right (positive x-axis).

We can only attribute this finding to limb dominance as it is well known that a larger percentage of the population is likely to be right limb dominant. One major deficit in phase I of the investigation was our failure to collect data on handedness and limb dominance on each subject. However, when comparing subjects with history or physical findings of right lower extremity injury, it can be noted that the percentage of time spent on the positive X axis is lower as compared to non-injured subjects. This indicates a tendency for skewing toward the non-involved limb. Conversely, in those subjects with history or physical findings of left lower extremity injury, the tendency is to skew toward the non-involved right limb, resulting in a higher percentage of time spent on the positive X axis as compared to non-injured subjects. We believe that a clear trend is evident in this data, however, additional testing will be required to verify whether or not handedness and limb dominance contribute overall scores.

Upon evaluating the RLR data for the dynamic balance group versus the involved side history and/or finding of lower extremity, it is apparent that the skewing away from the injured limb and limb dominance is not evident as with phase I data evaluating SBI. One possible explanation for the difference between the SBI test group and the DBI test group is the fact that visual biofeedback is required to perform the dynamic test and no visual cues are allowed with the static balance test. This may overshadow the apparent effect of “limb dominance” seen during the SBI testing.

Although not statistically significant, one can observe the exact opposite with the DBI testing. Subjects with an injury to one side actually use the opposite side to control the platform. As can be seen clinically, during dynamic testing, the strategy patient’s use is to “splint” or “block” the affected limb into extension, and control the platform with the uninvolved limb when forced to tilt to the involved side. Larger pathological populations will be needed to adequately evaluate this phenomenon.

Before comparing the performance data of the players and their respective balance indices, the hypothesis was that athletes with better performance scores would score better on balance testing. This assumption was false, except for the shuttle run. After rethinking the relationship, the correlations seem consistent with what one is actually measuring during the performance testing. The individual performance tests are measuring speed and acceleration (40 yard dash), strength and power (broad and vertical jump), quickness (4 square drill), and strength (Cybex isokinetic knee testing).

Only the shuttle run, which evaluates agility, has a positive correlation to SBI testing. In other words, static balance testing appears to be an independent measurable entity all on its own. The positive shuttle run relationship may be explained by the fact that balance is required to optimally perform the test. The results were the same for dynamic testing.

Balance Assessment Howard, Cawley, et al

Conclusions

The use of the balance assessment system appears to be a reliable and valid tool in a patient population consisting of elite college football players, irregardless of morphology. Balance aptitude did not display any statistically significant relationship with functional performance, except for the shuttle run. For injury patterns in elite college football players, dynamic balance testing seemed to discriminate between athletes without orthopaedic history/findings and athletes who had current injuries and who were unable to participate in workouts due to those injuries. In this population, percent right - left differences showed a positive relationship in predicting the injured limb during static balance testing and was not significant for dynamic balance testing.

Future considerations in balance testing must include:

- 1) further correlation to lower limb dominance,
- 2) static single leg testing, 3) dynamic single leg testing,
- 4) increase pathological population,
- 5) varying athletic populations,
- 6) female vs. male relationships,
- 7) age relationships,
- 8) duration of test to evaluate "fatigue",
- 9) training effects in normals, and
- 10) training effects following injuries to the lower extremity.

In conclusion, the balance assessment system raises more questions than it answers in the quest to evaluate proprioception and motor control of the lower extremity. Future studies need to be instituted to better understand balance and its relationship to proprioception and neuromuscular control. The investigators conclude that, with further testing and refinement, an instrumented unstable platform may become a valuable tool in the diagnosis, evaluation, and rehabilitation of neurosensory deficits resulting from soft tissue injury to the lower extremity.

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References

1. Anacker SL, Di Fabio RP: Influence of sensory inputs on standing balance in community-dwelling elders with a recent history of falling. *Phys Ther* 72(8): 575-581, 1992
2. Barrack RL, Skinner HB, Brunet ME, Cook SD: Joint laxity and proprioception in the knee. *The Physician and Sportsmedicine* 11: 6, 1983
3. Barrack RL, Skinner HB, Buckley SL: Proprioception in the anterior cruciate deficient knee. *Am J Sports Med* 17: 1-6, 1989
4. Barrack RL, Lund PJ, Skinner HB: Knee joint proprioception revisited. *J Sport Rehab* 3:18-42, 1994
5. Barrett DS: Proprioception and function after anterior cruciate reconstruction. *J Bone Joint Surg [Br]* 73-B: 833-7, 1991
6. Barrett DS, Cobb AG, Bentley G: Joint proprioception in normal, osteoarthritic and replaced knees. *J Bone Joint Surg [Br]* 73-B: 53-56, 1991
7. Branch TP, Cook J, Hutton WC: The effect of impaired proprioception on the response to an impulse. -Presented at the ORS, Washington, D.C., February, 1992
8. Carlo MS, Talbot RW: Evaluation of ankle joint proprioception following injection to the anterior talofibular ligament. *J Ortho Sports Phys Ther* 8: 70—76, 1986
9. Dvir Z, Koren E, Halpenn N: Knee joint position sense following reconstruction of the anterior cruciate ligament. *J Ortho Sports Phys Ther* 10: 117-120, 1988
10. Ekdahl C, Jamb GB, Anderson SI: Standing balance in healthy subjects. *Scan J Rehab Med* 21: 187-195, 1989
11. Faculjak PF, Firoozabakhsh KK, Wausher D, McGuire M: Balance characteristics of normal and anterior cruciate deficient knees. (ab) *Phys Ther* 72: s22, 1992
12. France P et al: Preliminary evaluation of the Breg K.A.T. effects of training in normals. *Isokinetics and Exercise Science* 2(3): 133-139, 1992
13. Freeman MAR, Dean MRE, Hanham IWF: The etiology and prevention of functional instability of the foot. *J Bone Joint Surg [Br]* 47: 678-685, 1965

14. Freeman MAR, Wyke B: Articular reflexes at the ankle joint. An electromyographic study of normal and abnormal influence of ankle-joint mechanoreceptors upon reflex activity in the leg muscles. *Br J Surg* 54:990-1001, 1967
15. Gam SN, Newton RA: Kinesthetic awareness in subjects with multiple ankle sprains. *Phys Ther* 68:1667-1671, 1988
16. Ghent R, Probst J, Denegar CR, Clemente FR: Assessment of the reliability of the Chatecx balance system. (ab) *Phys Ther* 72: s57, 1992
17. Grigg P: Peripheral neural mechanisms in proprioception. *J Sport Rehab* 3: 2—17, 1994
18. Grigg P, Finerman GA, Riley LH: Joint-position sense after total hip replacement. *J Bone Joint Surg [Am]* 55-A: 1016-1025, 1973
19. Halling AH, Howard ME, Cawley PW: Rehabilitation of anterior cruciate ligament injuries. *Clin Sports Med* 12:329-348, 1993
20. Hamson EL, Duenkel N, Dunlop R, Russell G: Evaluation of single-leg standing following anterior cruciate ligament surgery and rehabilitation. *Phys Ther* 74: 245-259, 1994
21. Harter RA, Ostemig LR, Singer KM, James SL, Larson RL, Jones DC: Long-term evaluation of knee stability and function following surgical reconstruction for anterior cruciate ligament insufficiency. *Am J Sports Med* 16: 434-443, 1988
22. Ihara H, Nakayama A: Dynamic joint control training for knee ligament injuries. *Am J Sports Med* 14: 309-315, 1986
23. Irrgang JJ, Whitney SL, Cox ED: Balance and proprioceptive training for rehabilitation of the lower extremity. *J Sport Rehab* 3: 68-83, 1994
24. Horak FB: Clinical measurement of postural control in adults. *Phys Ther* 67: 1881-1885, 1987
25. Iverson BD, Gossman MR, Shaddeau SH, Turner Jr ME: Balance performance, force production, and activity levels in noninstitutionalized men 60 to 90 years of age. *Phys Ther* 70: 348-355, 1990
26. Kennedy JC, Alexander IJ, Hayes KG: Nerve supply of the human knee and its functional importance. *Am J Sports Med* 10: 329-335, 1982

27. Klein BP, Blaha JD, Simons W: Anterior cruciate ligament deficient knees do not have altered proprioception. Presented at the ORS, Washington, D.C., February, 1992
28. Lentell GL, Katzman BS, Walters MR: The relationship between muscle function and ankle stability. *J Ortho Sports Phys Ther* 11: 605-611, 1990
29. Losse GM, Howard ME, Cawley PW: Correlation of lower extremity injury to balance indices: An investigation utilizing an instrumented unstable platform. Presented at the AAOS Specialty Day (AOSSM), New Orleans, LA, February, 1994
30. Mechling RW: Objective assessment of postural balance through use of the variable resistance balance board. *Phys Ther* 5: 685-688, 1986
31. Mizuta H, Shiraishi M, Kubota K, Kai K, Takagi K: A stabilometric technique for evaluation of functional instability in anterior cruciate ligament-deficient knee. *Clin J Sport Med* 2:235-239, 1992
32. Moritani T: Neuromuscular adaptations during the acquisition of muscle strength, power and motor tasks. *J Biomechanics* 26:95-107, 1993
33. Nyland J, Brosky T, Currier O, Nitz A, Cabom D: Review of the afferent neural system of the knee and its contribution to motor learning. *J Ortho Sports Phys Ther* 19: 2—II, 1994
34. Pitman MI, Nainzadeh N, Menche D, Gasalberti R, Song EK: The intraoperative evaluation of the neurosensory function of the anterior cruciate ligament in humans using somatosensory evoked potentials. *Arthroscopy* 4: 442-447, 1992
35. Safran MR, Caidwell GL, Fu FH: Proprioception considerations in surgery. *J Sport Rehab* 3: 105—115, 1994
36. Skinner HB, Barrack RL, Cook SD: Age-related decline in proprioception. *Clin Ortho Rel Res* 184: 208-211, 1982
37. Tropp H, Ekstrand J, Giliquist J: Factors affecting stabilometry recordings of single limb stance. *Am J Sports Med* 3: 185-188, 1984
38. Umphred DA: Neurological rehabilitation. Saint Louis, Mosby Company, 1985
39. Wilkerson GB, Nitz AJ: Dynamic ankle stability: Mechanical and neuromuscular interrelationships. *J Sport Rehab* 3: 43-57, 1994
40. Zatterstrom R, Friden T, Lindstrand A, Moritz U: The effect of physiotherapy on standing balance in chronic anterior cruciate ligament insufficiency. *Am J Sports Med* 22: 531 -536, 1994

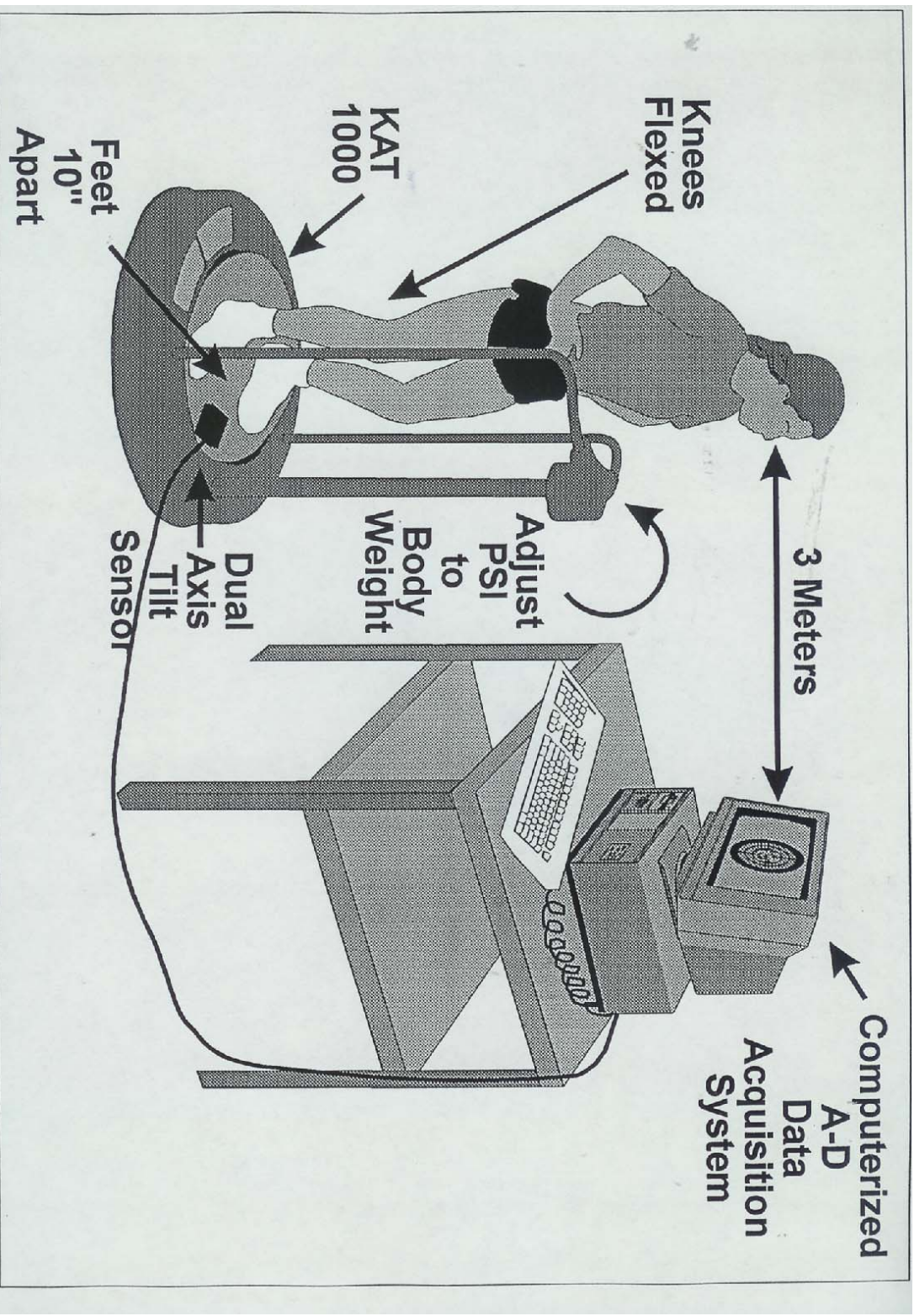


Figure 1

SBI Scores Distribution (All Tests)

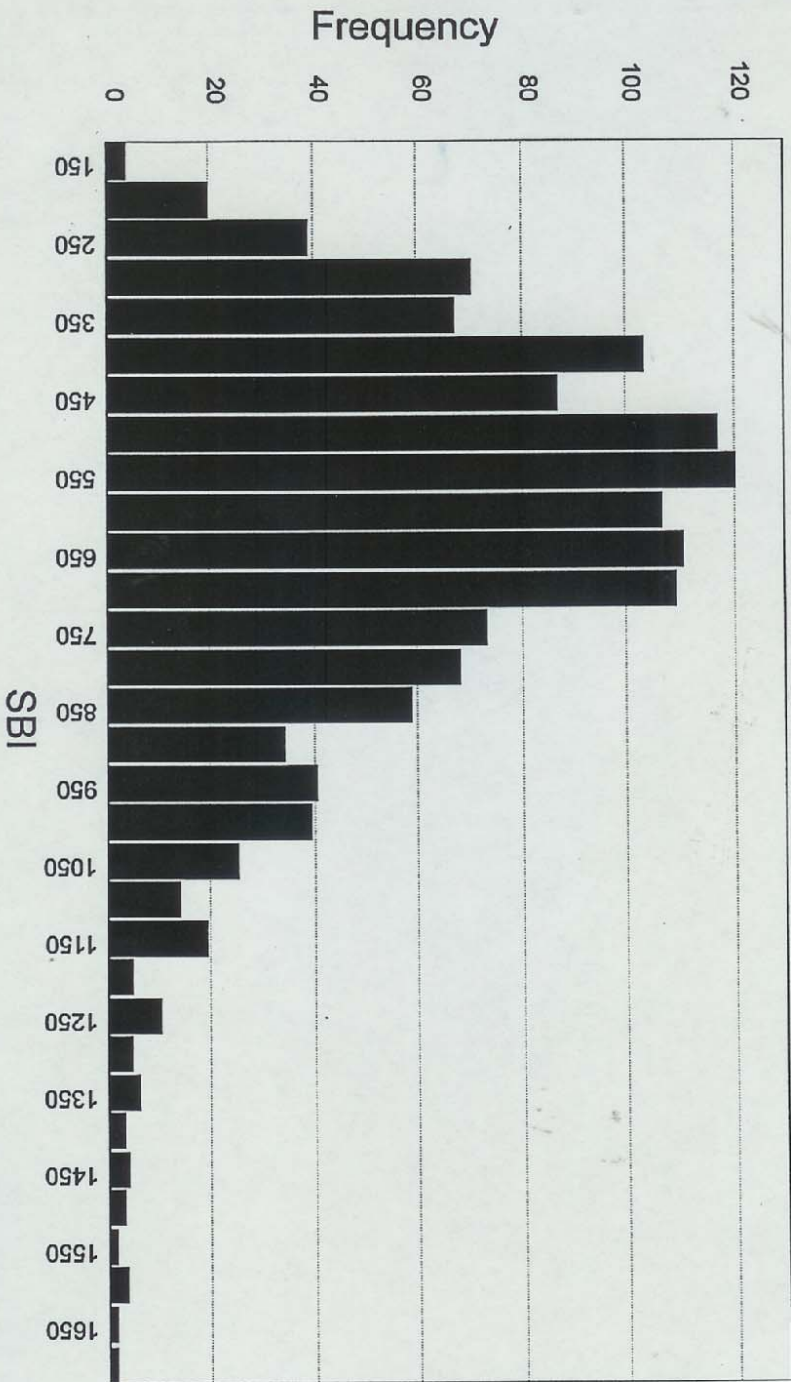


Figure 2

DBI Scores Distribution (All Tests)

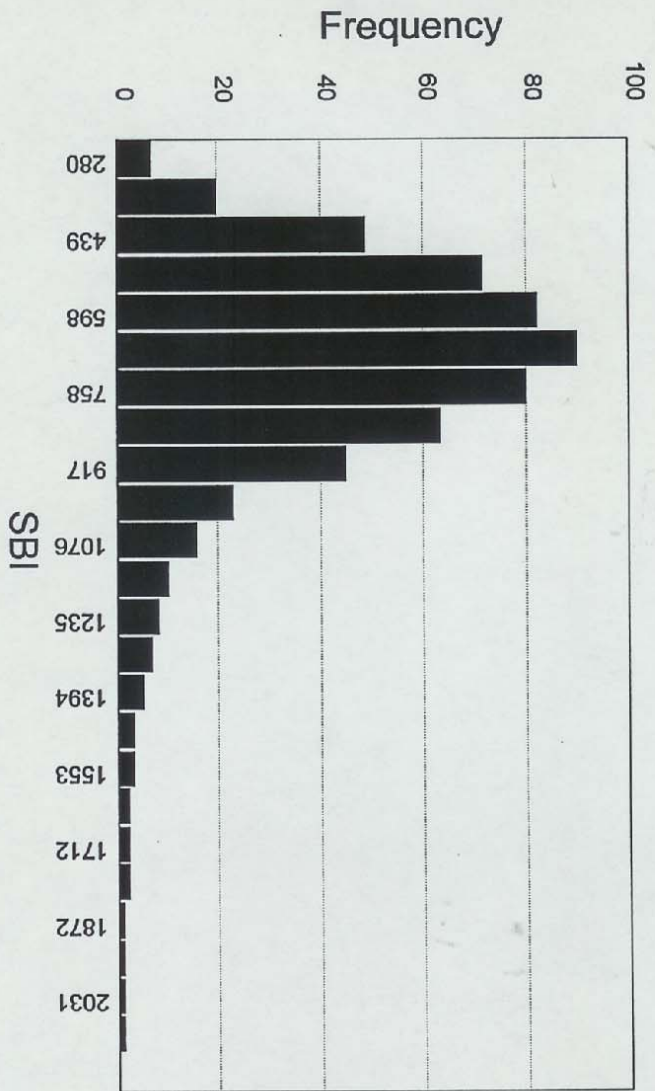


Figure 3

Raw Data
(All Balance Tests)

Group	Static Balance				Dynamic Balance			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Overall	722.47	248.78	182	1719	705.28	218.89	326	1844
Defensive Back	693.07	236.68	247	1564	672.62	182.87	326	1204
Defensive Line	767.33	263.06	359	1599	742.74	230.09	410	1398
Linebacker	788.63	299.48	281	1672	728.95	354.21	326	1420
Offensive Line	726.28	232.85	220	1719	713.00	155.67	378	1060
Kicker	678.56	151.80	358	1060	759.56	217.39	402	1374
Quarterback	661.59	236.03	319	1481	699.02	217.65	424	1152
Running Back	645.61	196.05	316	1315	677.76	253.70	420	1844
Tight End	656.33	176.72	369	1109	726.53	189.20	462	1082
Wide Out	678.28	246.09	300	1643	670.11	240.90	368	1406

Table 1

Correlations

Category	SBI	DBI
Weight	0.026	0.063
Height	N/A	0.153
40 Yard Dash	0.142	0.175
Broad Jump	-0.075	-0.285
4 Square	0.064	0.652
Shuttle Run	0.865	0.837
Vertical Jump	-0.140	-0.149
Cybox Torque	0.192	0.206

Table 2

SBI Data

(Grouped by Lower Extremity History & Findings)

Group	Mean	SD	(N)
No History	683.91	182.94	40
Head Injury History	672.80	134.56	40
Knee Injury History	729.69	174.86	134
Ankle Injury History	721.62	180.68	135
Foot Injury History	739.06	197.50	74
Lower Extremity Fracture History	741.19	177.45	34
No Physical Findings	698.56	180.90	212
+ Physical Findings	748.83	172.58	116
+ Knee Findings	726.11	176.92	55
+ Ankle Findings	738.60	120.92	24
+ Foot Findings	748.56	171.49	26
+ Lower Extremity Fracture Findings	837.00	113.26	11

Table 3

DBI Data

(Grouped by Lower Extremity History & Findings)

Group	Mean	SD	(N)
No History of L.E. Injury	685.64	204.72	48
Concussion History	725.56	186.56	44
Knee Injury History	732.58	177.45	114
Ankle Injury History	721.36	156.23	79
Foot Injury History	765.12	182.36	43
Lower Extremity Fracture History	752.67	145.69	37
Lower Extremity Muscle Injury History	772.91	189.51	67
No Lower Extremity Physical Findings	698.56	212.04	188
+ Lower Extremity Findings (All)	758.36	226.23	114
+ Lower Extremity Findings (Able to Practice)	736.49	202.69	85
+ Lower Extremity Findings (Unable to Practice)	853.24	172.39	29
+ Knee Findings	748.42	184.46	65
+ Ankle Findings	784.08	234.52	25
+ Foot Findings	746.25	102.89	8
+ Lower Extremity Fracture Findings	289.00	0.00	1
+ Lower Extremity Muscle Findings	812.64	328.00	17

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*

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(+ Statistically Significant Between * (P=0.004))

Table 4

Static Balance

(Right - Left Ratio Data)

Group	Mean	SD	(N)
No Lower Extremity Findings	0.255	0.115	212
Right Knee Findings	0.141	0.098	25
Left Knee Findings	0.313	0.223	27
Right ACL Findings	0.158	0.095	8
Left ACL Findings	0.420	0.174	9
Right Ankle Findings	0.185	0.095	10
Left Ankle Findings	0.339	0.121	14
Right Foot Findings	0.195	0.146	11
Left Foot Findings	0.308	0.083	15
Right Lower Extremity Fracture Findings	0.172	0.079	5
Left Lower Extremity Fracture Findings	0.575	0.245	6

Table 5

Dynamic Balance
(Right - Left Ratio Data)

Group	Mean	SD	(N)
No History of Lower Extremity Injury	0.001	0.113	48
No Lower Extremity Findings	0.010	0.106	188
+ Lower Extremity Findings	0.005	0.108	114
Right All Findings	-0.012	0.115	51
Left All Findings	0.014	0.107	63
Right Knee Findings	-0.023	0.095	32
Left Knee Findings	0.010	0.111	33
Right ACL Findings	-0.037	0.168	10
Left ACL Findings	0.043	0.121	4
Right Ankle Findings	-0.043	0.183	7
Left Ankle Findings	0.092	0.075	18
Right Foot Findings	-0.015	0.117	4
Left Foot Findings	-0.043	0.090	4

Table 6

Dynamic Balance

Right - Left Ratio Data
vs
Limb Dominance

Group	Mean	SD	Minimum	Maximum	(N)	
Right Leg Dominant	Test 1	0.017	0.148	-0.410	0.500	276
	Test 2	0.003	0.146	-0.380	0.450	276
Left Leg Dominant	Test 1	-0.007	0.164	-0.290	0.410	26
	Test 2	-0.007	0.147	-0.240	0.260	26

Table 7