PROSPECTIVE FUNCTIONAL PERFORMANCE TESTING AND LOWER EXTREMITY INJURY INCIDENCE IN ADOLESCENT ATHLETES

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ABSTRACT

The purpose of this study was to prospectively investigate if a battery of functional performance tests could be used as a preseason screening tool to identify adolescent athletes at risk for sports-related lower extremity injury via comparison of injured and uninjured subjects. Ninety-five adolescent volleyball, basketball and soccer athletes (female, n=62; male, n=38; mean age = 14.4±1.6) participated. Each subject performed a battery of functional performance tests during the preseason, referred to in the present study as the "Lower Extremity Grading System" (LEGS). The LEGS assessment included: triple hop for distance, star excursion balance test, double leg lowering maneuver, drop jump video test, and multi-stage fitness test. Subjects were monitored throughout their designated sport season(s), which consisted of a six-month surveillance period. The schools certified athletic trainer recorded all injuries. Subjects were divided into groups according to gender and injury incidence (acute lower extremity injury vs. uninjured). Univariate general linear model (GLM) was used to assess differences between groups. Pearson product moment correlation coefficients were determined between variables of interest. The receiver-operator characteristic (ROC) analysis was used to determine the cut-off score. The prospective mean LEGS composite scores were significantly lower between the injured and uninjured groups in both genders (males: 19.06±3.59 vs. 21.90±2.44; females: 19.48±3.35 vs. 22.10±3.06 injured and uninjured, respectively)($p < .05$). The ROC analysis determined the cut-off at ≤20 for both genders (sensitivity=.71, specificity=.81, for males; sensitivity=.67, specificity=.69, for females)($p<.05$), suggesting moderate predictability for acute noncontact lower extremity injuries. Furthermore, significant positive correlations were found between the LEGS composite score and the multi-stage fitness test (r=.474, p=.003) in male subjects, suggesting a relationship between functional performance, aerobic capacity, and potential injury risk. Identifying individuals who are at greatest risk and prescribing corrective, neuromuscular, and cardiovascular exercise at the appropriate time during developmental stages for adolescent athletes may reduce sports-related injury risk.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Part I:

INTRODUCTION

More than half of all high school students participate in some form of athletics each year, making up a population of over 7 million adolescent student-athletes.[1] High school athletes sustain an estimated 1.5 million injuries each year with the ankle and knee being the most common sites of injury.[2-5] Severe injuries negatively affect the injured athlete's health, result in the athlete missing a large part of his or her season, and often burden the health care system as they are more likely to require advanced medical treatment such as surgery.[2] Due to the shear number of injury occurrences and detrimental consequences, previous authors have suggested a need for implementation of specific injury prevention strategies for the ankle and knee joints via identifying modifiable injury risk factors.[2, 4-6]

Previous authors have expressed the importance of longitudinal studies when evaluating injury risk factors (i.e. demographic, biomechanic, fitness level, etc.) through prospective injury surveillance.[7-10] There has been a reported relationship between intrinsic static and dynamic factors that may contribute to increased risk of suffering acute lower extremity injuries in sports.[9, 11, 12] Intrinsic risk factors include demographics (previous history of injury)[13], anthropometric variables (BMI, age, gender)[13-15], postural stability (balance)[8, 16], fatigue[9, 17, 18], and physical performance measures (jump-landing, single leg hopping, core stability, cardiorespiratory fitness[19-23]. Functional tests such as the drop-jump video test, star excursion balance test, double leg lowering maneuver, triple hop for distance test, and the multi-stage fitness test have been presented in the literature as reliable and valid assessments for jump-landing mechanics, dynamic balance, core stability, lower limb strength and power, and cardiorespiratory fitness, respectively.[19, 24-28] Functional tests have been used to assess components of sport performance (strength, power, agility), determine readiness for return to sport, evaluate effectiveness of neuromuscular training interventions, and predict injury of the lower extremity.[29-33] An advantage of functional tests are that they require minimal personnel, are quick to administer, and do not require special equipment.[31]

Due to the high number of adolescent athletes and subsequent lower extremity injuries, improvements of injury prevention strategies with emphasis on clinic-based and practical assessments (time, equipment, finances, etc.) are warranted. Therefore, the purpose of this study was to prospectively investigate if a battery of functional performance tests could be used as a preseason-screening tool to identify adolescent athletes at risk for sports-related lower extremity injury via comparison of injured and uninjured subjects.

METHODS

Experimental Approach to the Problem

The present study, using a prospective field-based cohort design, investigated whether a battery of preseason functional performance tests could identify lower extremity injury occurrence in adolescent student-athletes. The preseason functional performance test battery included tests that have been previously validated separately and in combination with other athletic tests but have not been administered as a collective assessment. This battery of tests, which included the drop jump video test, star excursion balance test, double leg lowering maneuver, and the triple hop for distance test, is referred to below as the "Lower Extremity Grading System" (LEGS). The LEGS assessment was designed to provide sports medicine and strength/conditioning professionals with an objective, quantifiable composite score, which includes functional performance data regarding the lower extremity and trunk/core.

Subjects

One hundred male and female athletes between the ages of 12 and 17 years (14.44 ± 1.65 years) were recruited from a local private school and were chosen as a sample of convenience. Sample size was determined by performing a *priori* power analysis using G*Power statistical software (Version 3.1.9.2) with power set at 0.8. As participants in intermediate and upper school athletics, all subjects played at least one of three sports: soccer (n = 22), volleyball (n = 14), or basketball (n = 64). Sports were chosen based upon the common occurrence of noncontact acute lower extremity injuries involved with sport participation and high-risk maneuvers.[2] All subjects completed preparticipation health history questionnaires to rule out current pathological conditions and contraindications to study participation, which were evaluated by a physician. *Exclusionary criteria* included: incomplete pre-participation physical exam, and/or inability to physically perform any of the five required assessments. Prior to study participation all procedures were explained to each subject. Subjects and their parents/guardians read and signed assent and consent forms and video assent and consent forms that were approved by the university institutional review board for human subjects (Appendix C).

Injury Surveillance Protocol. Subjects were divided into groups according to gender and injury incidence. Those who sustained an acute lower extremity injury were placed in the injured group and those who did not sustain an acute lower extremity injury were pooled in the control group. Data were then analyzed for differences between groups. Additionally, the injured subjects were then matched with an equal number of control subjects based on gender, age, height, and body mass for further analysis. Subjects were monitored throughout their designated sport season(s) (2014-15) which consisted of a six-month surveillance period. The schools certified athletic trainer (ATC) and principal investigator (ATC, CSCS) were responsible for documenting and recording all injuries that occurred throughout the sports seasons. Sports injury was defined as an injury during athletic practice or game that caused restricted participation or inability to participate in the current or next scheduled practice or game. The present study was particularly concerned with reporting acute noncontact injuries to the lower extremity (e.g. ACL tear, ankle sprain), as research has shown potential in risk reduction through neuromuscular training for these types of injuries.[29, 30, 34] The ATC recorded athlete characteristics, date of injury, injured body part (right or left), a detailed history (i.e. onset, injury mechanism, type of athletic event), type of injury (i.e. ligament sprain, muscular strain), and date of return to unrestricted participation.

Procedures

Data were collected by the same four ATCs at all testing sessions. Anthropometric data were recorded before all testing procedures and included height, body mass, BMI (body mass index), age, date of birth, grade, sport, and level of sport participation by the principal investigator (PI). All testing was performed in the high school's gymnasium. Before testing, subjects conducted a dynamic warm-up (5 minutes) led by the PI. Subjects were then divided into four different groups, two for each gender. Each group started at a different test station. The starting (test) position was randomly assigned and included synchronous clockwise rotation of all groups. Functional test time(mins/secs): per rotation, per rest period, and per overall time to completion, were recorded with hand-held stopwatches. Standardized oral instructions for each test were rehearsed and read by the ATCs to all test groups (Appendix C). Standardized instructions were designed to maintain consistency of testing procedures, decrease instructional time, and allow concise and precise data collection. Incorrect test performance required that the test be restarted after a minimum 30-second rest period. No corrective feedback was given to subjects.

The Triple Hop for Distance Test (THD) evaluated maximal hopping distance on a single leg and was assessed in centimeters (cm) with a standard tape measure fixed to the ground, perpendicular to the starting line. Subjects started with their right leg, standing with the great toe on the starting line and performed three consecutive maximal hops forward on the same leg, using arm swing. The ATC measured the distance hopped from the starting line to the point where the toe struck the ground upon completing the third hop. Subjects repeated testing procedures with the left leg. All subjects were allowed one to three practice trials (self-selected) on each leg and then completed three total test trials on each leg with a 30 second rest between trials. Practice trials were limited to three per leg to avoid fatigue. The test was repeated if the subject was unable to complete a triple hop without losing his/her balance and contacting the ground with the opposite leg. The maximum distance (MaxD) achieved during the three trials was recorded in centimeters and used for analysis.[27]

The Star Excursion Balance test (SEBT) was used to record single-leg reach distance in cm(s) on each leg assessed with a standard cloth tape measure. Subjects performed the SEBT by standing in the middle of a testing grid with three cloth tape measures, anchored to the ground via white athletic tape, placed at 90-degree angles to each other. The subject stood on a single leg in the center of the grid, with the most distal aspect of the foot at the starting line keeping the hands on the hips. While maintaining single-leg stance, the subject was asked to reach with the non-stance leg in the anterior, posterior, and medial directions. Right leg scores are considered reaching with the right leg while balancing on the left; strengths and limitations are shown on the left (stance) leg. Left leg scores are considered reaching with the left leg while balancing on the right; strengths and limitations are shown on the right (stance) leg. Subjects were instructed to keep shoes on, were not allowed to touch the ground with the reaching leg during any part of the reach, and were instructed to move any way possible to achieve maximum reach distance without moving the support foot. The maximal reach was the furthest reach down the line and was observed visually by the tester. The trial was complete after the subject returned to the starting point placing the reach leg next to the stance leg. Each subject was allowed four practice trials in each direction and had to complete three successful reaches in all three directions with each leg. The trial may have been discarded and repeated if the subject (1) failed to maintain unilateral stance, (2) lifted or moved the stance foot from the grid (i.e. heel comes off the ground), (3) touched down with the reach foot, or (4) failed to return the reach foot to the starting position. Average and maximum reach distances (MaxD) in each direction were recorded in cm(s) and normalized according to leg length of the stance leg in order to adjust for variances of different anthropometrical variables. Star excursion balance test scores were expressed as a percentage of leg length.[35]

The Double Leg Lowering Maneuver (DLLM). Prior to the start of this test, the same tester (ATC, PT) measured and recorded true leg length with a Gulick tape measure (cm) for all subjects; leg length was used for post-testing normalization procedures of the SEBT scores (as stated above). True leg length was quantified for each leg with the patient supine, and defined as measurement from the anterior superior iliac spine (ASIS) to the distal end of the medial malleolus. The DLLM was assessed with a hand-held inclinometer (Johnson Tool 700 Magnetic Angle Locator) to assess slope of inclination in degrees and was placed along the extended legs over the estimated middle of thigh. The subject began supine with their hands to their side flat on the table. The same tester (ATC, PT) then passively raised the subject's lower extremities (with the knees extended) to a vertical position of 90 degrees (starting point). The subject was then asked to lower both legs while maintaining the lumbar spine parallel (neutral spinal position) to the test surface (performing an abdominal bracing procedure) to prevent anterior pelvic motion. The point where the tester palpated and observed anterior pelvic rotation, the test trial was concluded and the hip angle was measured with the inclinometer. Subjects were allowed one to three practice trials then three test trials were recorded, with permissible 30 seconds of rest between test trials.[36] In the present study, the DLLM score was calculated by subtracting the average angle (in degrees) from 90º (starting position).

The Drop Jump Video Test (DJV). A Sony Mini DV camcorder (Sony Corp of America, New York, NY) was used to record jump landing mechanics, placed on a 102 cm high stand, positioned approximately 366 cm in front of a box that was 30 cm in height and 38 cm in width. Jump landing mechanics were analyzed post-testing session via Dartfish Motion Analysis Software (ProSuite version 4.0.9.0) where lower limb separation distances at the hip and knee were calculated. Immediately before each subject performed the DJV test, the same ATC placed two sets of 1.5 x 1.5 inch florescent pink reference markers over the ASIS and center of patella for each limb. Subject's performed the DJV by first stepping off the box, landing, and immediately performing a maximum vertical jump. No specific directions were provided regarding how to land or jump; the subjects were only instructed to land straight in front of the box to allow proper camera data collection. Subjects were allowed one to three practice trials, and then three test jump-lands were recorded, allowing 30 seconds of rest between jumps. Two markers were placed on the box exactly 100 centimeters apart in order to calibrate the Dartfish Motion Analysis computer software. Hip separation distance (HSD) and knee separation distance (KSD) were identified and calculated via Dartfish by the same tester (PI) using the known 100 cm distance as the reference point. Hip separation distance was measured while standing erect on top of the box and defined as the distance between the most prominent point of each anterior superior iliac spine. Knee separation distance was measured at the lowest point of each jump landing prior to transition to takeoff into the vertical jump and was defined as the distance between the centers of the patellae. The average absolute knee separation distance during three successful trials was recorded in cm(s) and then normalized relative to HSD to yield a percentage for each subject.[19, 37]

The Multi-Stage Fitness Test (MSFT). After completion of the four-abovementioned functional tests, and prior to the MSFT, a five-minute rest period was provided. The MSFT was used to evaluate maximal oxygen consumption (VO_2 max)[28, 38], providing field-based data regarding aerobic fitness and fatigue and thus allowing for comparisons between injured and control groups. The subjects were required to perform a shuttle run back and forth along 20 meters (m), keeping in time with a series of signals on a compact disc by touching the appropriate end line in time with each audio signal. The frequency of the audible signals (and hence running speed) was progressively increased until the subjects reached volitional exhaustion and could no longer maintain pace with the audio signals. VO_2 max was estimated using correlation regression data described by Ramsbottom et al.[38]

Statistical Analyses

All data were analyzed using SPSS Statistics Version 22.0.0.0 (IBM, Armonk, New York, USA), with an alpha level set at .05 to determine statistical significance. Descriptive statistics were generated and Pearson product-moment correlation coefficients were determined between variables of interest. Subjects were divided into groups according to gender and injury (acute lower extremity injury, non-injured). Univariate general linear model (GLM) was used to assess differences in each functional test variable using absolute data between injured and control groups. Results of all functional tests were then scaled using linear regression, which allowed for the normalization of data for each test with scores ranging on a scale from 0 to 10. Scaling data involved computing the mean ± 3 standard deviations (SDs) for each test variable according to absolute scores for males and females. The data were then entered into regression equation models (see Table 1) with the fixed notations: the mean equaling a score of '5 out of 10', – 3 SDs equaling a score of '1 out of 10', and + 3 SDs equaling a score of '10 out of 10'. Utilizing the scaled measurements, the scores for the four functional tests (THD, SEBT, DLLM, and DJV) were added and the sum was characterized as the Lower Extremity Grading System (LEGS) composite score. The LEGS composite score was calculated using the equation below:

LEGS Composite = (DLLM scaled) + (SEBT mean of scaled right and left anterior reach) + (THD mean of scaled right and left MaxD) + (DJV absolute KSD scaled)

Receiver-operator characteristic (ROC) curves were used to determine cut-off scores for both males and females in the LEGS composite score that maximized sensitivity and specificity. The area under the curve (AUC) was calculated using the ROC analysis to measure the accuracy of the LEGS composite test as a predictor of injury. Positive predictive values (PPV) were defined in the present study as the probability that subjects with a positive screening test will truly sustain an acute lower extremity injury and were calculated using the following equation:

PPV = True Positive / (True Positive + False Positive).

Table 1. Regression equations used for scaling data for all subjects and according to gender (y = mx + b).

Functional Test Variable	Females (n = 47)	Males (n = 38)
DLLM**	y = 0.1482(DLLM) + 0.8734	y = 0.1604(DLLM) + 1.0563
SEBT Right Anterior*	y = 0.253(SEBTR) – 12.988	y = 0.2423(SEBTR) – 12.376
SEBT Left Anterior*	y = 0.214(SEBTL) – 10.57	y = 0.2762(SEBTL) – 14.658
THD Right MaxD†	y = 0.0293(THDR) – 7.2108	y = 0.0144(THDR) – 3.2046
THD Left MaxD†	y = 0.0258(THDL) – 5.5665	y = 0.0134(THDL) – 2.4636
DJV Absolute KSD¶	y = 0.2841(KSD) + 0.5038	y = 0.173(KSD) + 0.3887
DJV NKSD§	y = 0.0659(NKSD) + 0.4358	y = 0.0439(NKSD) + 0.249
MSFT††	y = 1.0176(MSFT) – 0.7243	y = 0.6929(MSFT) – 1.0091

**Double leg lowering maneuver = (average of 3 trials) – 90; degrees

*Star excursion balance test = (average of 3 trials in cm) ÷ (Leg length) x 100; anterior direction for right/left legs reported as percentage of leg length

†Triple hop for distance MaxD = maximum distance of 3 trials on right/left leg; centimeters

¶Drop jump video test absolute knee separation distance (KSD) = average of 3 trials; KSD defined as the distance between the patellae measured via Dartfish in centimeters

§Drop jump video test normalized KSD = (Avg Absolute KSD ÷ Hip separation distance) x100; reported as percentage of hip width

††MSFT = shuttle level reached during 20 meter volitional maximal exhaustion running test

RESULTS

Demographic characteristics of injured and control groups according to gender are provided in Table 2. There were no statistical significant differences in demographic variables between groups ($p > .05$). A total of 95 subjects (57 females, 38 males) were included in the statistical analyses by the end of the six-month injury surveillance period. Fifteen females and seven males sustained an acute lower extremity injury with no previous history of injury and were included as the injured groups. Of the injured females, two suffered noncontact anterior cruciate ligament (ACL) ruptures confirmed by MRI and 13 suffered acute ankle sprains. All seven males suffered acute ankle sprains. Forty-two females and thirty-one males were included as the control groups (no reported lower extremity injuries and no previous history of injury). A total of five subjects were excluded from statistical analyses as a result of incurring other non-acute lower extremity injuries (overuse knee injuries) during the prospective injury surveillance period.

Table 2. Injured and control subject demographic characteristics (mean ± SD).

Females	**Overall, n = 57**	**Injured, n = 15**	**Control, n = 42**
Age (years)	14.2 ± 1.6	14.7 ± 1.7	14.0 ± 1.5
Height (cm)	161.6 ± 6.6	164.1 ± 6.5	161.0 ± 6.4
Body Mass (kg)	55.9±13.4	57.1 ± 9.2	55.5±14.6
BMI (kg/m^2)	21.2 ± 4.2	21.2 ± 2.5	21.2 ± 4.6
Leg Length Right (cm)	86.6 ± 4.4	88.2 ± 4.8	86.1 ± 4.1
Leg Length Left (cm)	86.5 ± 4.4	88.1 ± 4.7	86.1 ± 4.1
Hip Separation Distance (cm)	22.9 ± 2.4	23.2 ± 1.8	22.8 ± 2.6
Sport Experience (years)	4.8 ± 2.7	5.2 ± 2.2	4.6 ± 2.9
Males	**Overall, n = 38**	**Injured, n = 7**	**Control, n = 31**
Age (years)	14.8 ± 1.6	14.6 ± 1.7	14.9 ± 1.6
Height (cm)	168.1 ± 9.8	171.3 ± 6.6	167.3±10.4
Body Mass (kg)	62.9±14.9	70.8±14.4	61.1±14.6
BMI (kg/m^2)	22.0 ± 3.8	24.1 ± 4.8	21.5 ± 3.5
Leg Length Right (cm)	89.4 ± 5.5	92.2 ± 4.9	88.8 ± 5.5
Leg Length Left (cm)	89.4 ± 5.5	92.0 ± 5.4	88.9 ± 5.4
Hip Separation Distance (cm)	24.7 ± 2.6	26.6 ± 3.1	24.3 ± 2.3
Sport Experience (years)	5.8 ± 2.7	5.4 ± 2.9	5.8 ± 2.8

Statistical means, standard deviations (SD), and ranges of the LEGS functional tests results for injured and controls are presented in Table 3. Univariate GLM indicated significant differences between groups for the DLLM and the DJV tests in females and only with the DJV test in males (Table 4). The DLLM average scores of the injured females were significantly lower than the scores of the control females (23.5 ± 9.7º and 32.63 ± 9.54º), respectively ($p < .05$). The DJV mean absolute KSD (14.35 ± 3.47 cm and 17.93 ± 5.56 cm) was significantly lower for the injured females compared to the control females, respectively ($p < .05$). Similarly, mean normalized knee separation distance (NKSD) for the injured females compared to the control females were significantly lower (61.73 ± 13.70% and 78.88 ± 24.45%, respectively) as were the NKSD of the injured males compared to their controls (86.68 ± 14.57% and 121.59 ± 34.44%, respectively) ($p < .05$). There were no significant differences in the SEBT or the THD between injured and control groups for males and females ($p > .05$).

Table 3. Functional performance test scores, including absolute and normalized, according to gender and categorized by injured and control for both genders.

			DLLM**	SEBT Anterior*	SEBT Posterior*	SEBT Medial*	THD R MaxD†	THD L MaxD†	DJV Absolute KSD††	DJV Normalized KSD§
Female	*Control*	n=42								
		Mean	32.22	76.44	83.09	93.85	435.18	423.15	17.93	79.18
		SD	9.80	6.11	7.32	6.39	50.37	59.39	5.56	24.23
		Range	18–58	64–91	67–99	83–106	353-561	297-569	9–33	48–151
	Injured	n=15								
		Mean	23.55	76.34	87.86	96.50	419.26	426.21	14.35	59.23
		SD	9.69	9.50	10.10	8.91	50.89	55.72	3.47	11.70
		Range	5–43	57–91	68–107	76–111	345-498	335-516	9–21	45–91
Male	*Control*	n=31								
		Mean	27.25	76.44	93.01	101.04	596.49	587.14	29.61	121.59
		SD	9.72	5.20	7.60	7.24	100.45	108.05	9.05	34.44
		Range	8–50	68–87	75–108	90–117	269-754	264-752	15–44	60–182
	Injured	n=7								
		Mean	24.04	72.23	92.90	98.92	584.92	545.37	22.92	86.68
		SD	8.43	4.73	13.03	8.73	134.39	136.89	3.71	14.57
		Range	8–30	67–80	78–109	90–111	294-701	269-681	17–28	67–108

**Double leg lowering maneuver = (average of 3 trials) – 90; degrees

*Star excursion balance test = (max distance of 3 trials in cm) ÷ (leg length of stance leg) x 100; reach directions were averaged between right/leg legs and reported as a single mean score; expressed as a percentage of leg length

†Triple hop for distance MaxD = maximum distance of 3 trials on right /left leg; centimeters

††Drop jump video test absolute knee separation distance (KSD) = average of 3 trials; KSD defined as the distance between the patellae measured via Dartfish in centimeters

§Drop jump video test normalized KSD = (Avg Absolute KSD ÷ Hip separation distance) x100; reported as percentage of hip width

Table 4. Univariate GLM results for significant functional test variables between injured and controls, grouped by gender (mean ± SD). n(%)

Functional Test	Injured	Control	F	*p*
Females (n=57)	*n=15 (26%)*	*n=42 (74%)*		
DLLM**	22.10 ± 9.69	32.63 ± 9.54	9.93	.003
DJV Absolute KSD*	14.35 ± 3.47	17.93 ± 5.56	5.47	.023
DJV NKSD†	61.73±13.70	78.88±24.45	6.58	.013
Males (n=38)	*n=7 (18%)*	*n=31 (82%)*		
DJV NKSD†	86.68±14.57	121.59±34.44	6.79	.013

**Double leg lowering maneuver = (average of 3 trials) – 90; degrees

*Drop jump video test absolute knee separation distance (KSD) = average of 3 trials; defined as the distance between the patellae measured via Dartfish in centimeters

†Drop jump video test normalized KSD = (Avg Absolute KSD ÷ Hip separation distance) x100; reported as percentage of hip width

Results of the multi-stage fitness test (MSFT) are presented in Table 5. Univariate GLM failed to identify any significant differences on performance of the MSFT between the injured and control groups ($p > .05$). Means, SDs and ranges of the LEGS composite scores are presented in Table 6. Mean composite scores for injured versus controls were 19.0 ± 3.5 vs. 21.9 ± 2.4 for males and 19.4 ± 3.3 vs. 22.1 ± 3.0 for females, respectively. Results indicated that there were significant differences in the LEGS composite score between injured and control groups for both genders ($p < .05$) (see Table 7). The ROC analysis determined the cut-off score of 20 (total scoring range: 1–40) for the LEGS composite in both males and females. Area under the curve (AUC) was statistically significant for both males and females (AUC = .765, $p = .030$ and AUC=.694, $p = .029$, respectively). The ROC analysis revealed that the sensitivity and specificity were 71% and 81% for males and 67% and 69% for females, respectively (see Figure 1). Results indicated that, among those who had a positive screening test (LEGS composite score ≤ 20), the probability of sustaining an acute lower extremity injury was 45% for males and 48% for females. When the LEGS composite score was combined with the MSFT (aerobic fitness measure), the statistical difference between injured and control groups remained for the females ($p = .016$), but not for the males ($p = .061$). Additionally, significant positive correlations were found between the LEGS composite score and the MSFT shuttle level ($r = 0.474$, $p = .003$), the MSFT estimated VO_2 max ($r=0.468$, $p = .003$), and the overall time to fatigue ($r = 0.456$, $p = .004$) in male subjects (Figures 2 and 3). The female subjects failed to demonstrate similar correlations between the overall functional test score and MSFT performance.

Table 5. Multi-stage fitness test (MSFT) variables according to gender and categorized by injured and control.

			MSFT Shuttle Level*	MSFT VO_2 Max**	Time to Fatigue†
Female	*Control*	n=42			
		Mean	6.00	33.14	5:16
		SD	1.49	4.68	1:51
		Range	2–9	22–43	1–8
	Injured	n=15			
		Mean	5.83	32.65	4:54
		SD	1.47	4.64	1:58
		Range	3–8	26–41	2–8
Male	*Control*	n=31			
		Mean	9.20	43.65	8:47
		SD	2.12	7.10	2:05
		Range	5–13	32–56	5–12
	Injured	n=7			
		Mean	8.98	42.94	8:39
		SD	2.52	8.31	2:57
		Range	4–12	27–51	3–11

*MSFT = shuttle level reached during 20 meter volitional maximal exhaustion running test

**MSFT VO_2 Max: estimated using shuttle level and linear regression reported by Ramsbottom[38]; mL/kg/min

†Time to fatigue: overall time to completion of test (volitional exhaustion); reported in minutes and seconds

Table 6. Lower Extremity Grading System (LEGS) composite scores with scaled values of combined functional tests according to gender and categorized by injured and control.

			LEGS Composite*	LEGS Composite Aerobic†
Female	*Control*	n=42		
		Mean	22.10	27.45
		SD	3.06	3.40
		Range	16–29	20–34
	Injured	n=15		
		Mean	19.48	24.70
		SD	3.35	4.42
		Range	12–24	16–31
Male	*Control*	n=31		
		Mean	21.90	27.25
		SD	2.44	3.37
		Range	16–26	19–33
	Injured	n=7		
		Mean	19.06	24.28
		SD	3.59	4.92
		Range	12–23	13–29

*LEGS Composite = (DLLM scaled) + (SEBT mean of scaled right and left anterior reach) + (THD mean of scaled right and left MaxD) + (DJV absolute KSD scaled); scale 1–40

†LEGS Composite Aerobic = (DLLM scaled) + (SEBT mean of scaled right and left anterior reach) + (THD mean of scaled right and left MaxD) + (DJV absolute KSD scaled); + (MSFT shuttle level); scale 1–50

Table 7. Univariate GLM results for LEGS composite scores between injured and controls, grouped by gender (mean ± SD). n(%)

Functional Test	Injured	Control	F	*p*
Females (n=57)	*n=15 (26%)*	*n=42 (74%)*		
LEGS Composite*	19.48 ± 3.35	22.10 ± 3.06	7.53	.008
LEGS Composite Aerobic†	24.70 ± 4.42	27.45 ± 3.40	6.23	.016
Males (n=38)	*n=7 (18%)*	*n=31 (82%)*		
LEGS Composite*	19.06 ± 3.59	21.90 ± 2.44	6.39	.016
LEGS Composite Aerobic†	24.28 ± 4.92	27.25 ± 3.37	3.73	.061

*LEGS Composite = (DLLM scaled) + (SEBT mean of scaled right and left anterior scaled) + (THD mean of scaled right and left MaxD) + (DJV absolute KSD); scale 1–40

†LEGS Composite Aerobic = (DLLM scaled) + (SEBT mean of scaled right and left anterior scaled) + (THD mean of scaled right and left MaxD) + (DJV absolute KSD) + (MSFT shuttle level); scale 1–50

Figure 1. Receiver-operator characteristic (ROC) curves for LEGS composite scores in males and females.

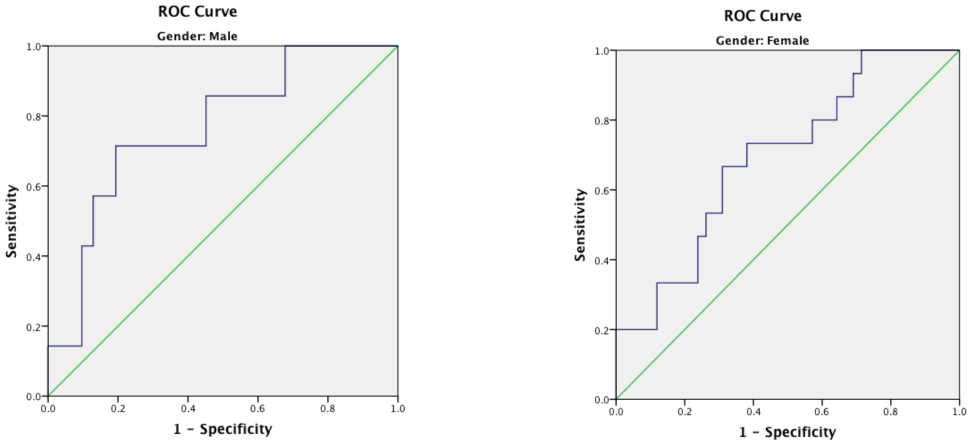
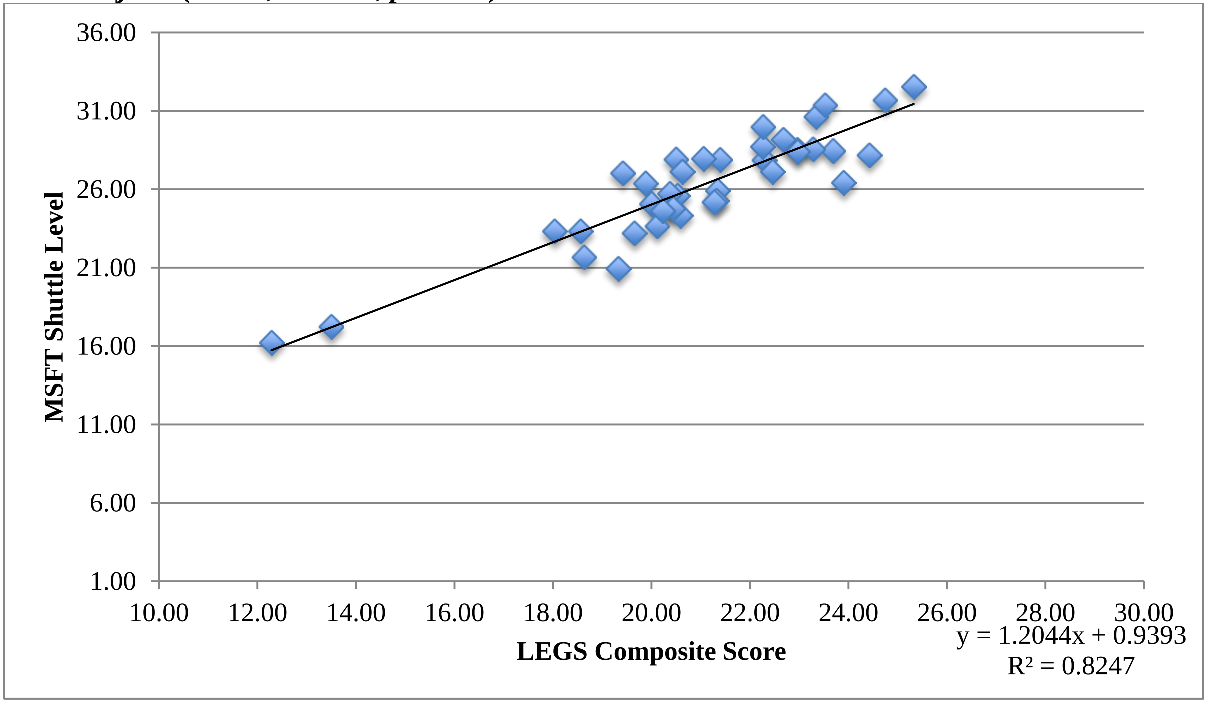


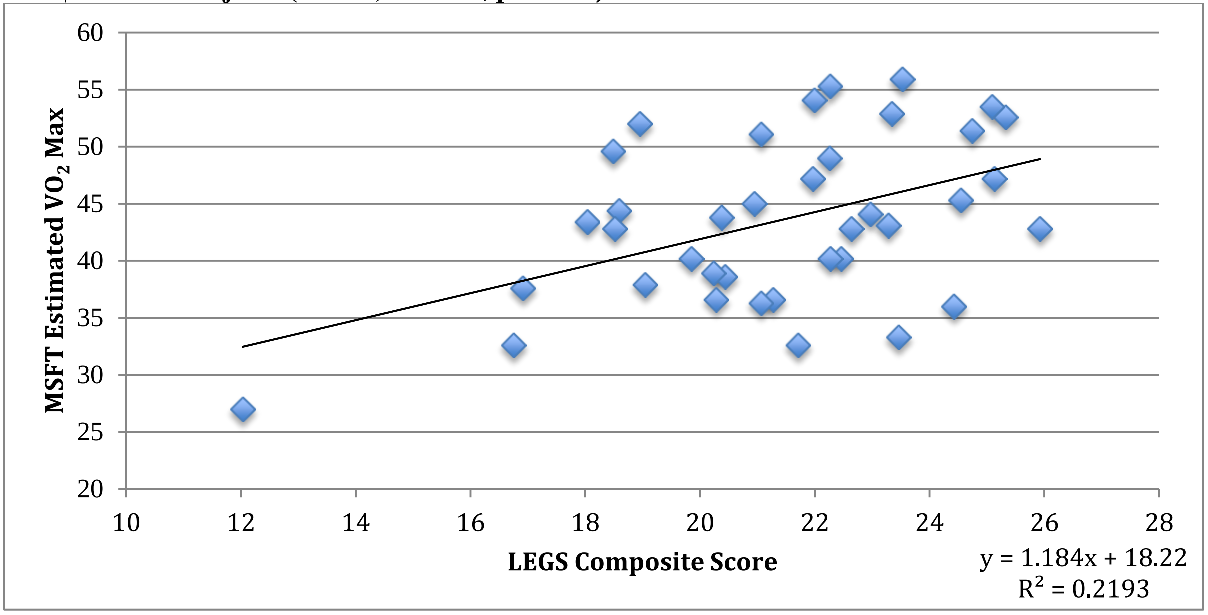
Figure 2. Correlation of LEGS functional test composite score* and MSFT shuttle level† in male subjects (n = 38, *r* = .474, *p* = .003)



*LEGS Composite = (DLLM scaled) + (SEBT mean of scaled right and left anterior scaled) + (THD mean of scaled right and left MaxD) + (DJV absolute KSD); scale 1–40

†MSFT = shuttle level reached during 20 meter volitional maximal exhaustion running test

Figure 3. Correlation of LEGS functional test composite score* and MSFT estimated VO_2 max† in male subjects (n = 38, *r* = .468, *p* = .003).



*LEGS Composite = (DLLM scaled) + (SEBT mean of scaled right and left anterior scaled) + (THD mean of scaled right and left MaxD) + (DJV absolute KSD); scale 1–40
†MSFT VO_2 Max: estimated using shuttle level and linear regression reported by Ramsbottom[38]; mL/kg/min

In addition to the original data set, the injured subjects were compared with the same number of controls matched for gender, age, height, and body mass; there were no significant differences between groups for the matching variables (see Table 8). Results were similar to the data previously analyzed between groups, except there was a significant difference between the injured leg and the matched controls leg noted during the SEBT for the male subjects (Table 9). The males mean anterior maximum reach distance (cm), normalized by leg length and expressed as a percentage, was significantly less for the injured compared to the matched controls (69.54 ± 4.70% and 76.49 ± 4.94%, respectively) (*p* = .019). The females mean anterior maximum reach distance of the injured leg was lower than the matched controls leg, yet there were no significant differences between groups (73.91 ± 8.83%, 77.36 ± 6.37% for injured and matched controls, respectively) (*p* = .231). There were no significant differences between groups in the posterior and medial reach directions for both genders (*p* > .05).

Table 8. Injured and matched control subject demographic characteristics (mean ± SD).

Females	**Overall, n = 30**	**Injured, n = 15**	**Control, n = 15**
Age (years)	14.2 ± 1.6	14.7 ± 1.7	14.8 ± 1.6
Height (cm)	161.6 ± 6.6	164.1 ± 6.6	164.5 ± 4.0
Body Mass (kg)	55.9±13.4	57.2 ± 9.2	57.5 ± 9.8
BMI (kg/m^2)	21.2 ± 4.2	21.1 ± 2.3	21.1 ± 3.0
Leg Length Right (cm)	88.2 ± 4.2	88.2 ± 4.8	88.0 ± 3.8
Leg Length Left (cm)	88.1 ± 4.2	88.1 ± 4.7	88.1 ± 3.7
Hip Separation Distance (cm)	23.2 ± 2.3	23.2 ± 1.8	23.3 ± 2.6
Sport Experience (years)	4.8 ± 2.7	5.2 ± 2.2	5.8 ± 3.2
Males	**Overall, n = 14**	**Injured, n = 7**	**Control, n = 7**
Age (years)	14.8 ± 1.6	14.5 ± 1.7	14.0 ± 1.4
Height (cm)	168.1 ± 9.8	171.7 ± 6.6	171.7 ± 5.0
Body Mass (kg)	62.9±14.9	70.8±14.4	66.2 ± 9.5
BMI (kg/m^2)	22.0 ± 3.8	24.1 ± 4.8	22.3 ± 2.4
Leg Length Right (cm)	91.7 ± 4.0	92.2 ± 4.9	91.3 ± 3.2
Leg Length Left (cm)	91.6 ± 4.2	92.0 ± 5.4	91.1 ± 3.0
Hip Separation Distance (cm)	26.1 ± 2.5	26.6 ± 3.1	25.5 ± 1.8
Sport Experience (years)	5.8 ± 2.7	5.4 ± 2.9	6.7 ± 3.4

Table 9. Univariate GLM results for significant functional test variables between injured and matched controls (mean ± SD).

Functional Test	**Injured**	**Control**	**F**	***p***
Females (n=30)	*n=15*	*n=15*		
DLLM**	23.55 ± 9.69	32.44±11.16	5.42	.027
DJV Absolute KSD*	14.35 ± 3.47	18.28 ± 3.66	9.28	.005
DJV NKSD†	61.73±13.70	79.79±20.27	8.20	.008
Males (n=14)	*n=7*	*n=7*		
SEBT Anterior MaxD††	69.54 ± 4.70	76.49 ± 4.94	7.32	.019

**Double leg lowering maneuver = (average of 3 trials) – 90; degrees

*Drop jump video test absolute knee separation distance (KSD) = average of 3 trials; KSD defined as the distance between the patellae measured via Dartfish in centimeters

†Drop jump video test normalized KSD = (Avg Absolute KSD ÷ Hip separation distance) x100; reported as percentage of hip width

††Star excursion balance test anterior MaxD = (maximum anterior reach of injured leg) ÷ (Leg length) x 100; percentage of leg length

DISCUSSION

The main finding of the present study was that the prospectively measured LEGS composite score was significantly different between the injured and control groups for both genders ($p < .05$). Additionally, knee separation distance during the drop jump video test and control of the core and pelvic neutral position during the double leg lowering maneuver were significantly different between the injured and the control groups ($p < .05$). When the injured males were matched with similar control males (n = 7 injured, n = 7 control), significant differences were found during the SEBT anterior reach direction between groups ($p = .019$). Additionally, the LEGS composite score correlated positively with the MSFT ($r = .474$, $p = .003$), identifying a significant relationship between functional test performance and aerobic fitness in male adolescent athletes. Therefore, these results support the use of the LEGS as a potential preparticipation assessment to identify athletes who may benefit from neuromuscular training to reduce risk of acute lower extremity injury incidence.

The reliability for the DJV has been reported with Intraclass Correlation Coefficients (ICCs) of 0.94 to 0.96.[19] Decreased knee separation distance on landing in both laboratory and field-based settings has been identified as a risk factor for noncontact acute lower extremity injuries.[19, 29, 30, 39] Knee separation distance has previously been normalized (NKSD) using hip intertrochanteric width and categorized into three zones: ≤ 60%, 60-80%, and > 80%.[19, 37] Previous researchers chose the percentile zones arbitrarily, but authors suggest 60% represents a distinctly abnormal lower limb alignment that is visually evident upon landing.[19] The present study defined hip separation distance (HSD) as the distance between the left and right anterior superior iliac spine (ASIS), as it is easier to locate during palpation than the greater trochanter. Additionally, data were analyzed using Dartfish two-dimensional video and it is more clinically accessible to measure ASIS (and less apt to be affected by body composition) in the frontal plane using small florescent square tape markers rather than the retroreflective spherical marker sets placed over the greater trochanter as commonly used in 3D video analysis. The females mean NKSD in the present study were significantly lower for the injured compared to the controls (61.73 ± 13.70% vs. 78.88 ± 24.45%, respectively); similarly, males mean NKSD were significantly lower for the injured compared to the controls (86.68 ± 14.57% vs. 121.59 ± 34.44%, respectively) ($p < .05$). Results indicated that 60% of the injured females landed with values equal to or less than 60% NKSD, while only 29% of female controls landed with values equal to or less than 60% NKSD (Table 10). In contrast, 0% of the injured males and 3% of the control males landed with ≤ 60% NKSD, while 71% and 87% (injured and controls respectively) of the male athletes landed with > 80% of NKSD. Therefore, the previously identified NKSD categories did not adequately relate to high-risk zones (≤ 60% NKSD) for the injured adolescent males.

Table 10. Frequency distribution of the drop jump video test results of normalized knee separation distance (NKSD) categories for both genders including injured and control subjects. n(%)

Females	**Overall, n = 57**	**Injured, n = 15**	**Control, n = 42**
NKSD			
≤ 60%	21 (37%)	9 (60%)	12 (29%)
60–80%	18 (31%)	4 (27%)	14 (33%)
> 80%	18 (31%)	2 (13%)	16 (38%)
Males	**Overall, n = 38**	**Injured, n = 7**	**Control, n = 31**
NKSD			
≤ 60%	1 (3%)	0 (0%)	1 (3%)
60–80%	5 (13%)	2 (29%)	3 (10%)
> 80%	32 (84%)	5 (71%)	27 (87%)

Initially, data from the present study were divided into three zones: ≤ 60%, 60-80%, > 80% NKSD, as described by Noyes et al.[19] The NKSD zones worked well when categorizing injured and control groups among female subjects. However, the previously reported NKSD percentile zones were not applicable for male subjects in the present study likely due to the difference in anatomical hip width used (ASIS vs. greater trochanter). Previous intertrochanteric HSD has been reported in adolescent females (41± 3 cm) and males (44 ± 5 cm).[19] The ASIS hip separation distance used in the present study resulted in lower mean HSD values for both adolescent females (23 ± 2 cm) and males (25 ± 3 cm). Subsequently, the previously identified NKSD categories may not be appropriate, especially when analyzing male adolescent athletes using the ASIS hip distance for normalization. Therefore, different categories were determined arbitrarily using the present study data (ASIS hip width) and NKSD was divided into three percentile zones for males: ≤ 85%, 85-100%, and ≥ 100% (100% = neutral landing position) (Table 11). Utilizing the newly developed NKSD percentile zones, the male subjects demonstrated NKSD frequencies similar to the female subjects that were categorized using the previously suggested percentile zones. Therefore, this adjustment in NKSD categorization serves as a potential tool for future DJV testing when ASIS hip separation distance is used for normalization procedures in male athletes.

Table 11. Frequency distribution of male subjects drop jump video test results of normalized knee separation (NKSD) categories proposed in the present study. n(%)

Males	Overall, n = 38	Injured, n = 7	Control, n = 31
NKSD			
≤ 85%	7 (18%)	3 (42%)	4 (12%)
85–100%	9 (24%)	2 (29%)	7 (23%)
> 100%	22 (58%)	2 (29%)	20 (65%)

The females mean absolute KSD was significantly different between the injured (14.35 ± 3.47 cm) and controls (17.93 ± 5.56 cm) ($p < .05$). These results are relatively low when compared to previously reported absolute KSD values on landing in female adolescent athletes (23 ± 9 cm).[19] For the males, the mean absolute KSD was 22.92 ± 3.71 cm and 29.61±9.05 cm for the injured and controls respectively. However, there were no significant differences revealed between groups ($p = .065$). This represents a similar range of scores reported in the literature for DJV testing of male adolescent athletes (22 ± 8 cm).[19] These results identify a relationship between frontal plane knee separation distance and acute lower extremity injury occurrence. Current findings support previous literature that advocates the use of field-based drop jump video assessments to evaluate athletes and begin neuromuscular training to improve knee separation distance upon landing to a more neutral lower limb alignment and decrease potential injury risk.[19, 29, 30, 37]

Another prospectively measured significant variable that was lower among injured females compared to uninjured females was the ability to control the core and pelvic neutral position determined by the double leg lowering maneuver (DLLM) ($p<.05$). The present study demonstrated that deficits in the DLLM, used for quantifying core stability, were significantly different between groups (mean = 22.10 ± 9.7º, 32.63 ± 9.5º, for the injured and controls respectively) ($p = .003$). The DLLM results of the injured male subjects were lower when comparing absolute mean scores (24.04 ± 8.43º vs. 27.25 ± 9.72º) to controls, but there was no statistical significant difference between groups (*p* = .426). Previous authors determined that athletes with decreased neuromuscular control of the body's core were at increased risk of knee injury (i.e. ACL) during a three-year prospective analysis.[40] Wilkerson et al.[22] demonstrated that core function assessed via static muscular endurance testing predicted knee injury risk in NCAA football players. Data from the present study support the idea that athletes should be evaluated for deficits in core stability before competition and be prophylactically treated with dynamic neuromuscular training to reduce lower extremity injury risk.[22, 40]

Reliability of the DLLM has been reported with ICCs equal to 0.98.[25] A grading scheme was developed by Kendall[36] which allows for categorization of subjects into five groups based on the degree level achieved during the lowering of the legs and maintenance of pelvic neutral.[36] However, Krause et al.[25] found that men are able to lower their legs to a position of 15º, therefore being unable to attain a grade of greater than "Good+". Additionally, Haladay et al.[41] reported that none of their subjects (n = 11, healthy aged 22 to 44 years) were able to attain a grade of greater than "Normal", even after eight weeks of stabilization exercise. Therefore, the grading system as described by Kendall[36] may reflect an unrealistic level of performance that many subject populations cannot achieve. The present study did not use this established grading system; rather the DLLM score was considered the average angle (in degrees) subtracted from 90 degrees (the starting position). Also, no previously published studies were found to report results of the DLLM in an adolescent population. Therefore, the DLLM data in the present study was not comparable to other previously reported DLLM measurements. Additionally, results of the DLLM have been shown to be variable when assessing pelvic motion between individuals, making it challenging for the clinician. The ability of the tester to palpate static musculoskeletal asymmetry has been found to vary by as much as ± 2.5 cm.[41] Therefore, the DLLM requires clinician experience and/or practice before administering, due to the required skill necessary to assess pelvic tilt in different individuals. The administrator of the DLLM in the present study was a licensed physical therapist (PT) and certified athletic trainer (ATC) with over 25 years of experience in both fields and was proficient in administering the DLLM.

The star excursion balance test (SEBT) is a measure of dynamic postural control, and has demonstrated high reliability with ICCs ranging from 0.89 to 0.94.[24, 42, 43] In the present study, when comparing the leg of the injured to the same leg of the matched controls, a significant difference was noted in the anterior reach direction for the male subjects ($p = .019$) (see Table 9). The males mean maximum anterior reach distance, normalized by leg length and expressed as a percentage, was 6.95% less for the injured leg compared to the same leg of the matched controls. The females mean maximum anterior reach distance of the injured leg was less than the matched controls leg (3.45% difference), but not statistically significant ($p = .231$). There were no significant differences between groups in the posterior and medial reach directions for both genders ($p > .05$). Previously, Gribble et al.[35] demonstrated that chronic ankle instability and fatigue to the lower extremity adversely affected dynamic postural control as assessed in the SEBT. In their study, physically active subjects with chronic ankle instability had significantly smaller reach distances in the anterior ($p = .026$), posterior ($p < .001$), and medial ($p = .022$) directions compared to their uninjured leg and also when compared to the same leg of the matched controls.[35] It should be noted that 91% of the reported injuries in the present study were to the ankle joint. Previous prospective research using logistic regression models has indicated that high school basketball players with an anterior reach distance difference greater than 4 cm between limbs were 2.5 times more likely to sustain a lower extremity injury ($p < .05$).[43] Similarly, authors have validated the SEBT in ACL-deficient subjects, revealing significant differences between the matched control group and the ACL-deficient limb for movement in the anterior ($p<.003$), lateral ($p < .005$), posteromedial ($p < .002$), and medial ($p < .001$) directions.[44] Delahunt et al.[45] found significant postural control deficits evident during posterior-medial ($p < .005$) and posterior-lateral ($p < .005$) reach directions between ACL reconstructed subjects and matched controls. The results of the present study provide evidence in correspondence with previous studies that support the use of the SEBT as a preparticipation examination tool to identify athletes who possess specific deficits in dynamic postural control and may begin modifying potential injury risk via neuromuscular training.[35, 43-45]

Performance on the multi-stage fitness test (MSFT) correlated positively with the LEGS composite functional test score in male subjects (*r* = .474, *p* = .003) and there was a significant difference in the LEGS composite score between the injured and control groups for males (19.06 ± 3.59 and 21.90 ± 2.44, respectively; *p* = .016) and females (19.48 ± 3.35 and 22.10 ± 3.06, respectively; *p* = .008). These results suggest a relationship between aerobic capacity, functional performance, and potential injury risk. Subjects who performed poorly overall on the LEGS functional performance tests tended to score low on the MSFT, thus reaching volitional maximal exhaustion earlier than subjects who scored higher on the functional performance tests (see Figures 2 and 3). Fatigue has been shown to adversely alter lower extremity landing biomechanics, decrease lower limb strength, and decrease dynamic balance[17, 18, 21]: all of which are reported risk factors for acute lower extremity injuries[8, 11, 20]. Furthermore, it has been reported that a high percentage (60%) of injuries occur during the latter end of a game or practice and the risk of suffering moderate to severe injuries increases compared to minor injuries.[9] Therefore, subjects who performed low on the LEGS composite score may benefit from improving aerobic endurance and VO_2 max and thus decreasing potential injury risk associated with fatigue. Recently, Konopka et al.[46] has shown that aerobic exercise acutely and chronically alters protein metabolism and induces skeletal muscle hypertrophy. This finding demonstrates an increase in the stability of the lower extremity with aerobic exercise training, and thus supports the present study's relationship between functional performance testing, aerobic fitness, and potential lower extremity injury.

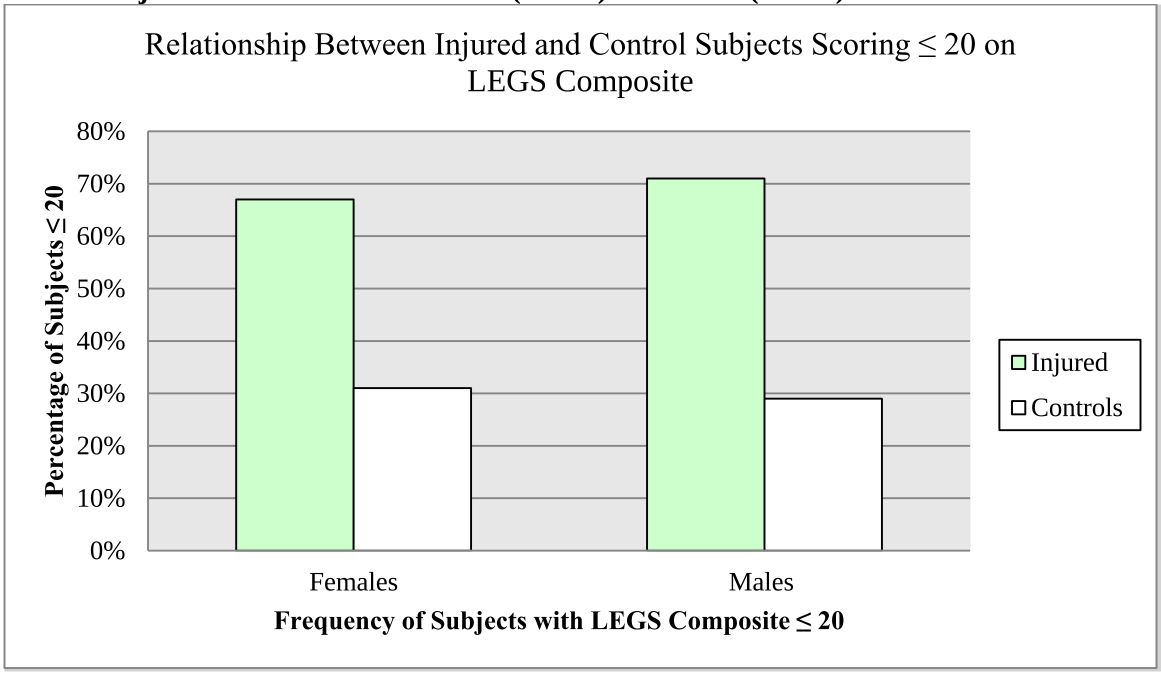
The test-retest reliability of the MSFT has been reported by others to be sufficient, with ICCs $\geq$ 0.90.[28, 47, 48] Multi-stage fitness test shuttle level (5.83 ± 1.47 vs. 6.00 ± 1.49, females) (8.98 ± 2.58 vs. 9.20 ± 2.12, males) and estimated VO_2 max (mL/kg/min) (32.65 ± 4.64 vs. 33.14 ± 4.68, females) (42.94 ± 8.31 vs. 43.65 ± 7.10, males) were slightly lower among injured compared to controls, respectively; however there were no statistical significance between groups (*p* > .05). Previous authors have demonstrated improvements in MSFT level and subsequent estimated VO_2 max via neuromuscular and aerobic conditioning programs in high school female basketball and soccer athletes.[29, 30] Thus the value of the MSFT seems to be its clinical effectiveness in evaluating aerobic fitness pre-and-post conditioning programs in field-based settings.

Hop tests are functional tests reported to require muscular strength, neuromuscular coordination, and joint stability in the lower limbs.[49] The triple hop for distance (THD) is a commonly described reliable (ICC = .95) and valid ($r^2 = .59$, $p<.01$,)[27, 49] test to assess lower limb strength and power on a single leg. Prospectively measured mean scores of the maximum hopped distances were lower for the injured leg compared to the matched control leg in both females (422.9 ± 53.7 cm and 441.28 ± 75.2 cm, injured and controls respectively) and males (566.78 ± 145.6 cm and 606.33 ± 64.7 cm, injured and controls respectively). However, there were no statistical significant differences in THD scores between groups ($p = .450$ and $p = .524$ in females and males, respectively). Also, there were no statistically significant differences in triple hop distance between the injured leg and the non-injured leg ($p = .858$ and $p = .387$ in females and males, respectively). Research has indicated that at the time of return to sport following ACL reconstruction, individuals with weaker quadriceps femoris strength (deficits > 15% on involved limb) demonstrate altered landing patterns and those with nearly symmetrical quadriceps femoris strength demonstrate landing patterns similar to uninjured individuals.[20] Schmitt et al.[20] suggest utilization of an objective quadriceps femoris strength measure clinically to help aid return to play decision-making post lower extremity injury. The advantage of the THD compared to the double-leg vertical jump and other bilateral jumping tests is that each leg can be evaluated independently so that asymmetries may be identified.[27, 49] No equipment other than a cloth tape measure is required for the THD, which may be particularly advantageous for various clinical settings, including high schools, universities, and orthopaedic clinics. Although THD performance was not statistically significant with prospective acute lower extremity injury incidence in the present study, its ability to identify subjects with strength deficits and altered landing mechanics[20] may justify its use as a preparticipation functional assessment tool. A value of the THD for clinicians is its ability to objectively measure lower limb strength and power when evaluating return to play readiness.[27, 49]

The functional performance tests used in the present study can be conducted as part of a collective assessment, referred to as the "Lower Extremity Grading System" (LEGS). The LEGS consists of scaling data using gender based linear regression equations and computing the sum for the following variables: 1) DLLM average, 2) SEBT average anterior reach distance of right and left legs, 3) DJV absolute knee separation distance, and 4) THD average max distance of right and left legs. The criteria for selection of the functional tests used in the LEGS assessment were repeated-measures reliability, validity in assessing desired measures of function, clinical applicability of testing procedures and instrumentation, and theorized relationship between injury risk factor and neuromuscular association. The creation of the LEGS composite score and its ability to differentiate between the injured and uninjured groups are of clinical importance, as the value in assessing injury risk via a composite score has been described. A functional test composite score has been previously validated using the Functional Movement Screen™ (FMS) in identifying injury risk in athletic and military populations.[23, 50-52] The FMS has been described as an injury predictor with a composite score less than or equal to 14 (out of 21) associated with an increased risk of serious injury in professional football players[50], lower extremity injury in collegiate female athletes[51], and acute lower extremity injury among college-aged physically active students[52].

The mean LEGS composite scores in the present study for the injured subjects were 19.0 ± 3.5 for males and 19.4 ± 3.3 for females. In previous studies, the ROC curve was used to determine the validity of functional tests as predictors of injury risk.[43, 50] The ROC analysis in the present study revealed that the LEGS composite score at the cut-off of ≤ 20 demonstrated sensitivities and specificities of 71% and 81% for males and 67% and 69% for females, respectively. When examining frequency counts of injured and control groups by the ROC cut-off score, results indicated that 71% of the injured and 29% of the control males had prospective composite scores of ≤ 20; similarly, 67% of the injured and 31% of the control females had prospective composite scores of ≤ 20 (Figure 4). Among those who had a positive screening test (LEGS composite score ≤20), the probability of sustaining an acute lower extremity injury (i.e. ACL tear, ankle sprain) was 45% for males and 48% for females. Therefore, these results suggest that the LEGS composite score of ≤ 20 has moderate predictability for acute lower extremity injuries in both genders. In the present study, when the LEGS composite score was combined with an aerobic fitness measure (the MSFT)(see Table 6), the significance between the injured and control groups decreased slightly for the females ($p = .008$ to $p = .016$) and failed to reach statistical significance for the males ($p = .061$). Previous research has shown that when a low FMS composite score (≤ 14) was combined with a poor aerobic fitness measure (3 mile run time), injury predictive value in military candidates increased significantly ($p < .05$).[23] Contrary to previous findings, the present study did not demonstrate an increase in predicative value by adding an aerobic fitness measure.

Figure 4. Frequency distribution for the LEGS composite cut-off score of 20 (out of 40) between injured and controls in females (n = 42) and males (n = 31).



The FMS has been described as one evaluation tool that attempts to assess the fundamental movement patterns of an individual.[23, 50] However, the FMS provides a measurement regarding the quality of fundamental movement and depends on the clinician’s ability to subjectively grade such movement. While the value in the FMS has been identified[23, 50-52], there are potential for untrained clinician biases, non-specified scores for types of injuries (traumatic vs. gradual onset) or location of injuries (lower extremity, upper extremity), and overall scores may not be well representative of athletic functional performance. In contrast, the LEGS is an objective, quantifiable athletic assessment that combines functional performance tests, which have been previously identified as reliable and valid as single test measures, and utilizes a normalization procedure to allow for combining scores into a single composite score. The LEGS composite score has demonstrated potential in identifying at risk athletes, as significant differences were noted in the LEGS composite score between the injured and the control groups in both females ($p = .008$) and males ($p = .016$). Therefore, if the LEGS can identify at risk athletes, prevention strategies can be employed based on the athletes specific scores. Similar to the FMS or any other comprehensive evaluation, the LEGS has potential to offer a proactive field-based assessment utilizing functional performance tests to provide feedback in regards to injury prevention, performance and wellness enhancement, and return to play readiness.

The main limitations of the present study were: not controlling for activities that subjects may have been involved in before and/or after the functional testing, lack of reporting athletic exposures during the injury surveillance period, and subsequent calculation of hazard ratio's and relative risk between functional performance testing and acute lower extremity injury occurrence. Additionally, external devices (e.g. ankle braces, knee supports, etc.) and leg dominance/handedness were not recorded. The limitations of the individual functional tests include the following: subjects kept their shoes on for the SEBT which may have affected their balance and overall scores; ankle separation distance was not measured during the DJV which may have provided insight to mechanisms of acute ankle/knee sprains; and VO_2 max was estimated with a 20 meter shuttle run performance (MSFT) to volitional exhaustion (scores may not be representative of true maximal aerobic capacity in the subjects tested). In general, other limitations include: relatively small sample size, short injury surveillance period, limited subject population (adolescent athletes in a single school), and lack of inter/intra-rater reliability reported for the LEGS composite assessment.

In summary, the prospectively measured overall LEGS composite score (composed of the triple hop for distance, the star excursion balance test, the double leg lowering maneuver, and the drop jump video test) was significantly different between the injured and control groups for both genders ($p < .05$). Additionally, there was a significant positive correlation between the LEGS composite score and aerobic fitness determined via the multi-stage fitness test ($r = .472$, $p = .003$). Results of the present study indicate that subjects with LEGS composite scores equal to or less than 20 may benefit from neuromuscular training interventions aimed at their specific weaknesses. It was concluded that the LEGS as a composite assessment offers: 1) a low technology tool that can be utilized by strength/conditioning coaches and healthcare professionals (i.e. ATCs, physical therapists, sports medicine physicians, etc.) to examine components of sport (strength, power, endurance) and injury risk factors (jump landing mechanics, core stability, dynamic balance) and 2) an affordable preparticipation functional screening tool to evaluate lower extremity deficiencies using objective quantifiable data.

Practical Applications

The LEGS can be administered before the start of the competitive season to assess deficiencies and thus modify potential injury risk through neuromuscular and cardiovascular training. In our experience, using a stations approach and four testers, the LEGS assessment can be administered to an average team of 20 athletes in less than 45 minutes. When studied prospectively, the injured subjects demonstrated lower scores compared to the uninjured (control) subjects during preseason testing. The majority of scores for the LEGS composite assessment of the injured subjects were ≤ 20 for either gender (71% and 67% for males and females respectively). Although no assessment tool can predict every injury, the LEGS assessment can be used to screen for lower extremity injury risk prior to athletic competition and subsequently be used in the development of individualized neuromuscular training programs to address deficiencies.

Part II:

REVIEW OF LITERATURE

Epidemiology & Incidence of Injury

Rechel et al.[3] examined the epidemiology of high school sports injuries in practice and competition. Researchers used prospective injury surveillance on athletes during the course of one school year involving five boys' sports (football, basketball, wrestling, and baseball) and four girls' sports (soccer, volleyball, basketball, and softball). Participants were chosen based on a nationally representative sample of 100 high schools throughout the U.S. The rate of injury per 1000 athletic exposures (AEs) was higher in competition (4.63 = 759 334) than in practice (1.69 = 683199) (RR = 2.73, 95% CI = 2.58, 2.90), resulting in a total injury rate of 2.51 injuries per 1000 AEs. Most injuries affected the lower extremities (ankle, knee, hip; n = 817944, 57.2%). Specifically, the most frequently injured body part was the ankle (n = 5 234 969, 22.7%). In practice, the highest rate of injury per 1000 AEs occurred in football (2.54), followed by wrestling (2.04) and boys' soccer (1.58). In competition, the highest rate of injury per 1000 AEs occurred in football (12.09), followed by girls (5.21) and boys (4.22) soccer. The 4350 reported injuries represent an estimated 1,442,533 injuries sustained by high school athletes participating in nine sports nationally.[3]

Le Gall et al.[4] prospectively investigated injury incidence in young elite female soccer players. A total of 119 players over an eight year period were followed and injuries were documented by a sports physician. Altogether, 619 injuries were documented; of these, 65% and 35% were sustained during training and matches, respectively. The risk of injury was greater in the youngest (under age 15) group compared with the oldest (under 19) group (RR = 1.7; 95% CI, 1.3-2.3). The majority (86%) of injuries were traumatic in nature. There were 52% minor injuries, 36% moderate injuries, and 12% severe injuries. Most injuries were to the lower extremities (83%), with the majority affecting the ankle (n = 157) and the most commonly diagnosed injury being an ankle sprain (17%). Twelve anterior cruciate ligament (ACL) ruptures were sustained, with the majority occurring during matches (n = 10). Re-injuries accounted for 4.4% of total injuries.[4]

Nelson et al.[5] investigated the incidence of ankle injuries by gender, sport, and type of exposure from using data drawn from a nationally representative sample of high schools. Certified athletic trainers (ATCs) from 100 U.S. high schools participated in injury documentation using an online injury surveillance reporting system (High School RIO). Specific sports studied were boys' football, boys' and girls' soccer, girls' volleyball, boys' and girls' basketball, boys' wrestling, boys' baseball, and girls' softball. Over the course of one year, athletes from the nine sports of interest sustained 905 ankle injuries during 1,730,764 AEs, for an ankle injury rate of 5.3 ankle injuries per 10,000 AEs. This number represents an estimated 326,396 ankle injuries sustained nationally (22.6% of all high school sports-related injuries). Ankle injuries were most frequently diagnosed as ligament sprains with incomplete tears (83.4%), with a total of 81.8% of ankle injuries as first-time sprains and 9.4% as recurrent injuries. An athlete was wearing an ankle brace when 7.8% of ankle injuries occurred. Ankle injuries most commonly caused athletes to miss less than 7 days of activity (51.7%), followed by 7 to 21 days of activity (33.9%), more than 22 days of activity (10.5%), and "other/unknown" (3.9%). Authors multiplied the median of the days lost in each category by the number of athletes in each category, and calculated that ankle injuries were responsible for an estimated 2,287,536 days of activity lost. Overall, girls had an ankle injury rate that was similar to boys (5.39 versus 5.15 per 10 000 AEs, respectively). Overall, ankle injury rates were higher in competition than in practice (95% CI = 2.26, 2.94; $P < .001$).[5]

Beynnon et al.[15] conducted a prospective cohort study of first-time ankle injuries among high school and college athletes. Athletes who competed in soccer, basketball, lacrosse, or field hockey at the varsity level were recruited and cumulated a total of 901 athletes (544 females and 357 males). Athletes were excluded if they had any of the following: history of foot, ankle, or knee ligament sprain; significant trauma to the lower extremity; surgery of the foot, ankle, or knee; systemic disease such as diabetes or rheumatoid arthritis; or a history of using knee braces, ankle braces, or tape during activity. Prior to the start of the athletic season, athletes underwent physical examination by the same investigator in order to ensure that the lower extremity joints were functioning normally. Evaluations consisted of: ankle laxity with the anterior drawer test and talar tilt test, anterior-posterior knee laxity (KT-1000), and varus-valgus knee laxity via clinical inspection at 20 degrees of knee flexion. Athletes were then monitored over a four-year period and ankle injuries were documented. Twenty-nine female athletes (5.3%) and 14 male athletes (3.9%) suffered injuries. The injury rate (IR) of ankle sprains for the female (0.97) and male (0.68) athletes did not differ significantly (*P* = .20). The relative risk (RR) of injury was 1.51 for the female athletes in comparison to the male athletes (95% CI = 0.79-2.86). When considering the high school athletes as a group, the difference in ankle IRs between the female (0.90) and male (0.63) athletes was not statistically significant (*P* = .29). There was no significant difference in the ankle IRs between the female (1.15) and male (0.78) college athletes (RR = 1.50; 95% CI = 0.50-4.48; *P* = .40). Female basketball players were found to be at a significantly greater risk than male basketball players (RR = 4.11; 95% CI = 0.91-18.60; *P* = .046). The sport-specific IRs for female and male athletes did not differ significantly among soccer athletes (RR = 0.69; 95% CI = 0.23-2.14; *P* = .52) or among lacrosse athletes (RR = 1.40; 95% CI = 0.39-4.96; *P* = .60). The risk of ankle injury for the college athletes did not differ significantly from that of the high school athletes (RR = 1.16; 95% CI = 0.61-2.21; *P* = .64). Also, female basketball players suffered a significantly greater incidence of ankle injuries (IR, 1.90) in comparison to lacrosse (IR = 0.62; RR = 2.81; 95% CI = 1.02-7.76; *P* = .045) but not in comparison to soccer (IR = 0.73) and field hockey (IR = 0.90) athletes.[15]

Stracciolini et al.[6] performed a retrospective cross-sectional analysis for the purpose of presenting descriptive data that could be used to help identify risk factors for youth sports injuries and examine differences between the injuries sustained by male and female athletes in a pediatric population. Upon compilation of medical records, a large cohort (2,133 total) of patients aged 5 to 17 years old (54% females, 46% males) with various types of sports injuries were analyzed. Over one third of female athletes (34.7%) had a history of overuse injuries. On average, male and female patients participated in a total of 2.4 activities. Females were primarily treated for overuse injuries (62.5%) and males were treated more for traumatic injuries (58.2%). The majority of patients in the male and female cohorts presented with lower extremity injuries (60.2%). Injury location differed by gender: 65.8% of the females sustained a lower extremity injury, 15.1% to the upper extremity, 6.7% to the hip/pelvis body region, and 11.3% to the spine. In comparison, 53.7% of the males sustained a lower extremity injury, 29.8% to the upper extremity, 3.7% to the hip/pelvis, and 8.2% to the spine. Approximately 40.2% of the females and 39.8% of the males underwent surgery as definitive treatment. Females with injuries to the lower extremity presented with patellofemoral knee pain leading the list (21.8%). The percentage of patients with patellofemoral knee pain in this study population was approximately three times greater in females than males (14.3% vs. 4.0%, respectively; $P < .001$). The second most common lower extremity diagnosis in females was anterior cruciate ligament (ACL) tears (13.5%). The leading lower extremity diagnoses in males were ACL (18.6%) tears, fracture (14.0%), and OCD (12.7%). There was no significant difference between the genders in the percentage of severe knee injuries including ACL tears ($P = .369$).[6]

Darrow et al.[2] examined severe sports injuries in a nationally representative sample of high school athletes. The certified athletic trainers (ATCs) at participating high schools reported athlete-exposures (AE) and injury information for nine sports weekly over the course of two academic years. Athletic-exposure was defined as participation in one practice or competition. Reportable injuries (1) were defined as injuries that occurred as a result of sport participation in an organized high school athletics practice or competition, (2) required medical attention by an ATC or physician, and (3) resulted in restriction of the sport participation in ≥1 day after the injury. Severe injury was defined as restriction of sport participation >21 days after the initial injury. Injury rates were calculated as the ratio of injuries per 1,000 AEs. Results revealed 1,378 severe injuries reported in nine sports, representing an estimated 446,715 severe injuries sustained nationally. Severe injuries accounted for 14.9% of all high school sports-related injuries. These injuries occurred during 3,550,141 AEs, for an injury rate of 0.39 per 1,000 AEs. The severe injury rate was higher in competition (0.79) than practice (0.24) (overall RR = 3.30; 95% CI = 2.97-3.67; P □□.001) in each sport. Football was found to have the highest severe injury rate per 1,000 AEs (0.69), followed by wrestling (0.52), girls' basketball (0.34), and girls' soccer (0.33). The two most common severely injured body sites were the knee (29.0%) and ankle (12.3%). The knee made up 81.8% of complete ligament sprains. Overall, 43.0% of severe injuries resulted in a time loss of □21 days, 56.8% in medical disqualification for the remainder of the season, and 0.3% in medical disqualification for the injured athletes' career. Approximately one in four (28.3%) severe injuries required surgery, with over half (53.9%) resulting in knee surgeries. Surgery was required most commonly with severe injuries that occurred in girls' basketball (38.2%) and girls' soccer (36.6%).[2]

Boys' and girls' soccer accounted for 10.5% and 15.0%, respectively, of all severe injuries.[2] Among all severe soccer injuries, the most commonly injured body parts were the knee (38.9%) and ankle (16.0%). A greater proportion of severe soccer injuries sustained by girls were to the knee (49.7%) compared with boys (23.3%), with 65% resulting in medical disqualification for the season. Mechanisms commonly leading to severe injuries were contact with another player (27.9%) and rotation around a planted foot/inversion (15.9%). Volleyball players sustained minimal rates of severe injuries, accounting for 3.9% of all severe injuries. Jumping/landing (23.8%) was the most common injury mechanism identified in volleyball, with the knee (31.9%) and ankle (28.0%) being most commonly injured. Boys' and girls' basketball accounted for 6.0% and 8.6%, respectively, of all severe injuries. The most commonly injured body parts were the knee (35.0%) and ankle (19.4%). Girls sustained a greater proportion of severe knee injuries (44.9%) than boys (20.7%) (95% CI = 1.38-3.41; $P < .001$). The most common mechanism of injury was jumping/landing (19.2%), while rebounding accounted for the largest proportion of severe injuries among both boys (30.9%) and girls (15.7%) basketball.[2]

In conclusion, injuries to the ankle and knee are the most common injuries sustained by adolescent athletes.[2-5] Studies have documented injury rates, relative risk, and other etiologic factors of acute ankle sprains according to gender, sport, type of exposure, and first-time injury. Ankle injury rates in females seem to be similar in males. The highest sports risk for an acute ankle injury for male and female comparable sports are basketball, soccer, and volleyball.[4, 6, 15] Acute lower extremity injuries have been reported to occur during a competition/game more often than during practice.[2-5] Authors established that first-time ankle injury for female athletes is associated with the type of sport; the risk of injury being highest for female basketball athletes. In contrast, for male athletes, the risk of first-time ankle injury is not associated with the type of sport.[15] Due to the shear number of injury occurrences and detrimental consequences, authors suggest a need for implementation of specific injury prevention strategies for the ankle and knee joints via identifying modifiable injury risk factors.[2, 4-6]

Lower Extremity Injury Risk Factors

Beynnon et al.[12] conducted a prospective investigation of the risk factors for inversion ankle ligament sprains. One hundred eighteen Division I National Collegiate Athletic Association (NCAA) varsity athletes (50 men and 68 women ranging between 18 and 23 years of age) who competed in lacrosse, soccer, or field hockey participated in this study. Prior to the start of the athletic season, potential ankle injury risk factors were measured, including: ankle joint laxities (modified Beighton method), anatomic alignment of the foot and ankle (non-weight bearing, goniometer), isometric ankle strength (isokinetic dynamometer), postural sway (anterior-posterior center of gravity), and muscle reaction time (electromyography). Subjects were then monitored throughout their designated sports season and injuries were documented. The number of ankle injuries per 1,000 person-days of exposure to sports was 1.6 for men and 2.2 for women. There were 13 injuries among the 68 women (19%) and seven injuries among the 50 men (13%), but these proportions were not significantly different. Women who played soccer had a higher incidence of ankle injury than those who played field hockey or lacrosse. There was no relationship between type of sport and incidence of injury for the men. Factors associated with ankle ligament injury differed for men compared to women. Women with increased tibial varum and calcaneal eversion range of motion were at greater risk of suffering ankle ligament trauma, while men with increased talar tilt were at greater risk. Generalized joint laxity, isometric ankle strength, postural stability, and muscle reaction time were unrelated to ankle injury.[12]

McGuine et al.[16] examined dynamic balance as a predictor of ankle injuries in high school basketball players. A total of 210 athletes (119 male, 91 female) with no previous history of injury over the past 12 months served as subjects. Preseason balance was assessed via measurements of postural sway with the NeuroCom New Balance Master (version 6.0). Testing to determine postural sway consisted of having subjects stand on one leg for three trials of 10 seconds with their eyes open, then repeated with their eyes closed. Balance on both left and right legs was measured. Certified Athletic Trainers in the high schools documented and recorded descriptive data for all ankle injuries. Postural sway was defined as the average degrees of sway per second (°S/S) for the 12 trials producing a compilation (COMP) score. Two hundred ten subjects participated in 14,655 athletic exposures. Twenty-three (10.9%) of the subjects sustained ankle sprains during the basketball season. Subjects who sustained ankle sprains had a preseason COMP score of 2.01 ± 0.32 (Mean ± SD), while athletes who did not sustain ankle injuries had a score of 1.74 ± 0.31. Higher postural sway scores corresponded to increased ankle sprain injury rates (p = 0.001). Subjects who demonstrated poor balance (high sway scores) had nearly seven times as many ankle sprains as subjects who had good balance (low sway scores) (p = 0.0002.).[16]

Willems et al.[11] researched the effects of preseason measurable intrinsic factors and their predisposition to ankle sprains in a male cohort. A total of 241 male physical education students were evaluated for possible intrinsic risk factors for inversion sprains at the beginning of their academic year. The evaluated intrinsic risk factors included anthropometrical characteristics, functional motor performances (including: flamingo balance, standing broad jump, shuttle run, and multi-stage fitness test), ankle joint position sense, isokinetic ankle muscle strength, lower leg alignment characteristics, postural control (via the Neurocom Balance Master), and muscle reaction time during a sudden inversion perturbation. Subjects were followed prospectively for one to three years. A total of 44 (18%) of the 241 male subjects sustained an inversion sprain; 4 sprained both ankles. Cox regression analysis revealed that male subjects with slower running speed (*P* = .019), less cardiorespiratory endurance (*P* = .022), less balance (*P* = .001), decreased dorsiflexion muscle strength (*P* = .036), decreased dorsiflexion range of motion (*P* = .013), less coordination (*P* = .037), and faster reaction of the tibialis anterior (*P* = .048) and gastrocnemius (*P* = .033) muscles are at greater risk of ankle sprains.[11]

Tyler et al.[13] examined the association between BMI (body mass index), history of previous ankle sprain, and risk of sustaining noncontact ankle sprains. A total of 152 football players from two different high schools underwent preseason evaluation. Height, body mass, history of previous ankle sprains, and ankle tape or brace use was recorded. Athletes were prospectively monitored over the course of two to three years. There were 24 ankle sprains, of which 15 were noncontact inversion sprains resulting in 17 missed games and 125 missed practices (incidence, 1.08 noncontact sprains per 1,000 athlete-exposures). Body mass index was also a risk factor (*P* □□.05): injury incidence was 0.52 for players with a normal body mass index, 1.05 for players at risk of overweight, and 2.03 for overweight players. Injury incidence was 0.22 for normal-weight players with no previous ankle sprain compared with 4.27 for overweight players who had a previous sprain. An overweight player who had a previous ankle sprain was 19 times more likely to sustain a noncontact ankle sprain than was a normal-weight player with no previous ankle sprain.[13]

Wang et al.[8] assessed injury risk factors for the prediction of ankle injuries in boy's high school basketball players. Forty-two (age, 16.5 ± 1.1 years) players without history of injury in the lower extremities within 6 months before recruitment were included. Biomechanic measurements including isokinetic ankle strength, 1-leg standing postural sway, and ankle joint dorsiflexion flexibility were performed before the basketball season by one physical therapist. Monthly questionnaires were sent out to all subjects in order to prospectively record the incidence of ankle injury during the season. Eighteen ankle sport injuries were recorded for 42 players during the follow-up season. High variation of postural sway in both anteroposterior and mediolateral directions corresponded to occurrences of ankle injuries (P = .01, odds ratio, 1.220; P<.001, odds ratio =1.216, respectively). All other variables were not associated with injury.[8]

Nilstad et al.[14] investigated risk factors for lower extremity injuries in elite female soccer players using a series of comprehensive screening tests and subsequent injury documentation. Prior to the start of the season, 173 females (age, 21.5 ± 4.1 years) participated in baseline screening tests along with questionnaires to collect basic demographic data, elite level experience, and injury history. The test order was randomized, and each player spent about eight hours in total to complete the test sessions, which also included information gathering, warm-up trials on all stations, and a lunch break. A comprehensive test battery was used to assess potential demographic, neuromuscular, and anatomic risk factors for injury. Risk factor screening measurements consisted of: maximal isokinetic quadriceps and hamstring strength (Technogym REV 9000 dynamometer), maximal hip abductor strength (handheld dynamometer), one repetition maximum leg press, dynamic balance (Star Excursion Balance Test), three-dimensional (3D) maximal knee valgus angles (Drop Jump Vertical Test), anterior-posterior knee joint laxity (KT-1000 arthrometer), generalized joint laxity (Beighton scale), and foot pronation (navicular drop test).[14]

A total of 171 lower extremity injuries in 107 players (62%) were recorded;

injuries to the knee (n= 53, 31%) and ankle (n= 40, 23%) were the most frequent.[14] Nearly one third of the injuries were severe, leading to an absence from soccer training and match play for ≥ 4 weeks. Multivariate analyses showed that a greater BMI (OR, 1.51; 95% CI, 1.21-1.90; *P* = .001) was the only factor significantly associated with new lower extremity injuries. A greater BMI was associated with new thigh injuries (OR, 1.51; 95% CI, 1.08-2.11; *P* = .01), a lower knee valgus angle in a drop-jump landing was associated with new ankle injuries (OR, 0.64; 95% CI, 0.41-1.00; *P* = .04), and a previous knee injury was associated with new lower leg and foot injuries (OR, 3.57; 95% CI, 1.27-9.99; *P* = .02). Younger players were more likely to sustain an ankle injury compared with older players. Higher maximal lower extremity strength in a leg press machine gave a 47% increased ankle injury risk per SD increase of relative strength, whereas players with greater maximal knee valgus angles in a vertical drop-jump landing or less foot pronation were less likely to suffer an injury. Nineteen previous ACL injuries were reported (18 noncontact), and a previous ACL injury in the right knee gave a 9-fold increased risk of sustaining a new knee injury in the same leg (OR, 9.08; 95% CI, 1.90-43.44; P = .006). Neither the demographic, neuromuscular, or anatomic factors nor a previous knee injury was associated with new knee injuries.[14]

Sman et al.[7] conducted a prospective study aimed to identify predictors of ankle syndesmosis injury in rugby players. Baseline measurements consisted of: ankle dorsiflexion range of motion via the weight-bearing lunge test; isokinetic ankle strength (hand-held dynamometer); calf muscular fatigue via the heel rise test; postural stability quantified by the Star Excursion Balance Test (SEBT); vertical jump height (Vertec™ device); lower limb strength and power measured by the triple hop for distance test; and foot type determined by the Foot Posture Index. Following baseline testing, participants were monitored over the course of one season (seven months) and injury data were recorded. A total of 202 male participants aged 21 ± 3.3 years were recruited, of whom 12 (5.9%) sustained an ankle syndesmosis injury confirmed through MRI. Fifty percent (n= 6) of the injured had a history of ankle sprain and two (16.5 %) reported a previous ankle syndesmosis injury. No significant predictors were identified; however a trend was visible. Participants who sustained an ankle injury during the season had a higher vertical jump (63.6 ± 8.2 cm) and further SEBT reach (80.5 ± 5.3 cm) during the preseason screening than participants who did not sustain an ankle injury (59.1 ± 7.8 cm and 77.9 ± 6.1 cm, respectively).[7]

In conclusion, research clearly identifies the value of longitudinal studies evaluating injury risk and factors (i.e. demographic, anatomic, biomechanic, etc.) through prospective injury surveillance.[7, 8] There is a reported relationship between static and dynamic factors that may contribute to increased risk of suffering acute lower extremity injuries in sports. Intrinsic risk factors include demographics (previous history of injury)[13], anthropometric variables (age, BMI)[14], postural stability (balance)[7], and functional performance measures (jump-landing, single leg hopping, core stability, cardiorespiratory fitness)[8, 11, 14].

Functional Tests: Reliability, Validity, & Injury Correlation

Lower Limb Strength and Power.

Bolgla et al.[49] reported on the reliability of four functional hop tests. Intraclass correlation coefficients (ICCs) and standard error of measurement (SEM) statistics, based on average day 1 and day 2 (re-test) scores, were used to estimate the reliability of each functional hop test. The hop tests included: single hop for distance, triple hop for distance, cross-over hop for distance, and 6 meter timed hop. Intraclass correlation coefficients ranged from .66 to .95, and SEM for distance hop tests ranged from 4.56 cm to 15.95 cm. The repeated measures ANOVA showed no significant difference ($p > .05$) between individual test trials for the triple hop for distance with average scores ranging from 422.3 cm to 439.1 cm. The only difference was noted for the single hop for distance. Authors concluded that this difference represented a learning effect not found with the other tests.[49]

Hamilton et al.[27] conducted a study to determine the extent to which the triple hop for distance (THD) predicts performance on clinical measures of power, strength, and balance in athletes. Forty collegiate soccer athletes (20 male, 20 female) took part in this study. Participants completed the Balance Error Scoring System (BESS) test, three trials each of the THD and vertical jump, and five repetitions each of concentric isokinetic quadriceps and hamstrings strength testing at 60°/s and 180°/s. Bivariate correlations and linear regression analyses determined that the THD was a strong predictor of vertical jump height, explaining 69.5% of variance. The THD was also a strong predictor of quadriceps and hamstrings strength at both 60°/s and 180°/s, predicting 49.0% and 58.8% of the variance, respectively.

Zebis et al.[53] conducted a prospective cohort study on fifty five elite female athletes, determining preactivity electromyography (EMG) of lower limb musculature during a standardized side-step cutting maneuver. Over the course of 2 seasons, five athletes sustained a confirmed non-contact ACL rupture. Before injury, all five players displayed a neuromuscular pattern that differed from noninjured players, characterized by reduced EMG preactivity for the semitendinosus (ST) and elevated EMG preactivity for the vastus lateralis (VL) ($P < .01$). Based on these findings, the authors categorized zones of risk, defining a high-risk zone as one standard deviation above the mean VL-ST difference. Thus decreased hamstring (ST) & increased quadriceps (VL) strength during an athletic task may increase risk for non-contact ACL injury.[53]

Schmitt et al.[20] conducted an investigation on the impact of quadriceps femoris (QF) strength asymmetry on knee landing biomechanics at the time of return to sport following anterior cruciate ligament reconstruction (ACL-R). Seventy-seven ACL reconstructed individuals were recruited and matched with forty-seven uninjured control (CTRL) individuals. Quadriceps femoris strength was assessed and quantified via isokinetic dynamometer during a maximal voluntary contraction and a Quadriceps Index was calculated (QI = [involved strength/uninvolved strength]*100%). The ACL-R group was subdivided based on QI: High Quadriceps (HQ, $QI \geq 90\%$) and Low-Quadriceps (LQ, $QI < 85\%$). Knee kinetics and kinematics were assessed via three-dimensional analysis during a bilateral drop jump task. Knee pain and symptoms were quantified via the Knee Injury and Osteoarthritis Outcome Score (KOOS). Results indicated that the LQ group demonstrated worse asymmetry in all kinetic and ground reaction force variables compared to the HQ and CTRL groups, including reduced involved limb peak knee external flexion moments ($p < .001$), reduced involved limb ($p = .003$) and increased uninvolved limb ($p = .005$) peak vertical ground reaction forces, and higher uninvolved limb peak loading rates ($p < .004$). There were no differences in the landing patterns between the HQ and CTRL groups on any variable (*p* > .05). The ACL-R group QF strength estimated limb symmetry during landing after controlling for graft type, meniscus injury, knee pain and symptoms. Authors concluded that at the time of return to sport following ACL-R, individuals with weaker QF strength (deficits > 15% on involved limb; QI < 85%) demonstrate altered landing patterns and those with nearly symmetrical QF strength demonstrate landing patterns similar to uninjured individuals.[20]

In conclusion, hop tests are functional tests reported to require muscular strength, neuromuscular coordination, and joint stability in the lower limbs.[49] The triple hop for distance (THD) is a commonly described reliable and valid test to assess lower limb strength and power on a single limb.[27] Schmitt et al.[20] suggest utilization of an objective quadriceps femoris strength measure clinically to help aid return to play decision-making post lower extremity injury. The value of the THD for clinicians lies in its ability to objectively measure lower limb strength and power in evaluating return to play readiness and unilateral asymmetry. The advantage of the THD compared to the double-leg vertical jump and other bilateral jumping tests is that each leg can be evaluated independently so that asymmetries may be identified. No equipment other than a cloth tape measure is required for the THD, which may be particularly advantageous for high schools, sports clubs, and other clinical settings with limited financial assets.[27]

Dynamic Balance and Postural Control.

Kinzey et al.[24] evaluated the reliability of the star excursion balance test (SEBT) using twenty subjects (9 males, 11 females) aged 18 to 34 years with no history of lower extremity injury or inner ear disorders. The test was setup using 4 lines, 1 vertical, 1 horizontal and 2 perpendicular intersecting lines positioned at 45-degree angles from the respected vertical and horizontal lines. A rectangle representing the starting point was placed in the center of the intersecting lines. A standard tape measure was used to quantify the distance (cm) from the center to the point each subject reached along the diagonal line using the distal part of the foot. Calculators were used to reduce the trial data into directional averages. Subjects completed 2 test sessions, 7 days apart. The test began when the subject started moving in any of the 4 directions: right anterior (RA), left anterior (LA), right posterior (RP), and left posterior (LP). Subjects were instructed to keep shoes on, were not allowed to touch the ground with the reaching leg during any part of the reach, and were instructed to move any way possible to achieve maximum reach distance without moving the support foot. The maximal reach was the furthest reach down the diagonal line and observed visually by the tester. Trial was complete after the subject returned to the starting point placing the reach leg next to stance leg. Five consecutive trials were completed before the subject began to reach in the next direction. Through subjective description, researchers noted what movement patterns each individual used for performing the SEBT, which was used later to identify possible differences between limbs. No recommendations concerning limb length were made during the test performance. Intraclass correlation coefficients for the four directions ranged from 0.67 to 0.87, with the highest estimates of reliability being reaches that were in the left diagonal direction (LA, LP) while the subjects stood on the right foot.[24]

Gribble et al.[42] conducted a reliability study to determine the interrater reliability of the SEBT using a group of investigators at two sites. A secondary purpose was to examine the interrater reliability when using normalized and nonnormalized performance scores on the SEBT. A total of 29 participants (19 women, 10 men) volunteered for this study. Prior to the test sessions, an investigator with more than 11 years of experience with the SEBT instructed the raters at the test site using standardized oral instructions and demonstration. This investigator then served as the practice model for the other raters at each site and established that the raters were properly instructed and could take the measures independently. Three reach directions—anterior (ANT), posteromedial (PM), and posterolateral (PL)—were recorded in centimeters and the results from the three directions were averaged to create a composite nonnormalized score. Using those four dependent variables (ANT, PM, PL, and composite), the nonnormalized scores (cm) were recorded and analyzed. The excursion distances in each direction (cm) were normalized via dividing by a participant’s leg length (cm) and multiplying by 100 (normalized maximum excursion distance) for the percentage score. Aside from the normalized and nonnormalized reaching distances, the mean and maximum values from the three test trials were analyzed, producing a total of 16 variables. The ICCs ranged from 0.86 to 0.92 for the normalized maximum excursion distances; ICCs for nonnormalized reach distances were stronger with values ranging from 0.89 to 0.94.[42]

Plisky et al.[43] performed a prospective surveillance study following boys and girls basketball teams at seven different high schools over the course of one season. Prior to the start of the basketball season, the anterior, posteromedial, and posterolateral SEBT reach and limb lengths of 235 high school basketball players were measured bilaterally. The Athletic Health Care System Daily Injury Report (DIR) was used to document time loss injuries. After normalizing for lower limb length, each reach distance, right/left reach distance difference, and composite reach distance were examined using odds ratio and logistic regression analyses. The reliability of the SEBT components had ICCs ranging from 0.82 to 0.87 and was 0.99 for the measurement of limb length. Logistic regression models indicated that players with an anterior right/left reach distance difference greater than 4 cm were 2.5 times more likely to sustain a lower extremity injury ($P < .05$). Girls with a composite reach distance less than 94.0% of their limb length were 6.5 times more likely to have a lower extremity injury ($P < .05$).[43]

Herrington et al.[44] compared SEBT performances of twenty-five ACL-D patients (17 male and 8 female) to twenty-five matched healthy control subjects. Comparisons of the ACL-D injured vs. uninjured limb and the matched limb of the control group were evaluated in eight different reach directions. Analysis using *t*-tests revealed significant differences between the control group and ACL-D limb for movement in the anterior ($P < .003$), lateral ($P < .005$), posteromedial ($P < .002$), and medial ($P < .001$) directions. The ACL-D limb exhibited worse dynamic postural-control than the limb of the control group, with performance differences between limbs ranging between 5% and 28%. Interestingly, in the ACL-D patients, their uninjured leg showed deficits compared to the control group in two of the four directions of the SEBT. This result may be indicative of a postural control deficit in these patients, which authors concluded may have predisposed them to the ACL injury and thus might have been prevented if prescreening or baseline testing had been administered.[44]

Delahunt et al.[45] conducted a similar laboratory-based study evaluating dynamic postural stability quantified by the SEBT and simultaneous hip and knee joint kinematic (3D) profiles of female athletes post ACL reconstruction (ACL-R). Fourteen ACL-R athletes were matched by age and gender with seventeen uninjured control subjects. Reach distances for each direction were quantified and expressed as a percentage of leg length. Results showed a difference between groups for both posterior-medial ($P < .005$) and posterior-lateral reach directions ($P < .005$). Contrary to previous studies,[43, 44] no difference between groups was observed for the anterior reach direction ($P < .016$). However, kinematic differences were noted during the anterior reach. The ACL-R group differed from control ($P <.05$), demonstrating increased hip adduction, less hip flexion, and less knee flexion.[45]

Gribble et al.[35] investigated the effects of fatigue and chronic ankle instability (CAI) on performance measures of dynamic postural control in physically active college-aged subjects (n = 30). Fourteen subjects with CAI were matched with 16 healthy controls, all of which participated in the 3 reach directions of the SEBT (anterior, medial, and posterior) before and after each fatigue condition. Reaching distance during the SEBT was measured (cm) while sagittal-plane kinematics of the stance leg, the leg that underwent the fatiguing task, were recorded via two-dimensional video. The fatiguing conditions (four) consisted of isokinetic dynamometer exercise protocols to induce fatigue to sagittal-plane movers of the hip, knee, and ankle; and performing a lunging task a maximum number of times. Results indicated that subjects with CAI had significantly smaller reach distances in the anterior ($P = .026$), medial ($P = .022$), and posterior ($P < .001$) directions compared to their uninjured leg and also when compared to the same leg of the matched controls. Authors demonstrated that CAI and fatigue to the lower extremity adversely affected dynamic postural control as assessed in the SEBT.[35]

Cinar-Medeni et al.[54] investigated the effects of postural stability and core endurance on lower extremity performance in ACL-reconstructed (ACL-R) patients. The purpose of this study was two-fold; 1) investigate the relationship between postural stability, core stability, knee laxity, and knee muscle strength, and 2) determine the relationship between lower extremity performance (via single-leg hop testing) and core stability, knee laxity and muscle strength in ACL-R patients. Twenty-eight ACL-R patients with a mean age of 28.03 years were recruited for this study and assessed after the 16th week in their respective post-operative rehabilitation programs. Anterior knee laxity was assessed with the Kneelax 3 arthrometer, measuring anterior tibial translation with 89- and 132- N forces. Concentric knee flexor and extensor muscle strength was evaluated with the ISOMED 2000 isokinetic dynamometer, using starting positions at angular velocities of 60 degrees/sec and 180 degrees/sec. Knee muscle strength scores were normalized by body weight. Core stability was assessed via isometric endurance tests, with results recorded in time to fatigue (inability to maintain test position). Four different isometric endurance tests were used—prone-bridge, side-bridge, Sorenson test (extensor endurance), and supine isometric chest raise, with test-retest reliability reported 0.78, 0.99, 0.78, 0.89, respectively. Single-limb postural stability was measured with the Biosway Portable System (Biodex) in eyes-open and eyes-closed conditions on a static surface and in an eyes-open condition on a foam surface. The output data from the system were overall sway index, mediolateral sway index (MLI), and anteroposterior sway index (API), with higher values indicating worse postural stability. The single-leg hop for distance test was performed to assess lower extremity performance, and the mean score of three trials was recorded. Results revealed that decreased core stability, decreased knee muscle strength, and increased knee laxity negatively affected single-limb postural stability ($P < .05$). Decreased knee muscle strength (isometric) was shown to negatively affect lower extremity performance, assessed via the single-leg hop for distance, in ACL-reconstructed patients ($P < .05$).[54]

In conclusion, the SEBT has been shown to be highly reliable (ICCs 0.89 to 0.94).[24] Research indicates that when the raters have been trained by an experienced rater, the SEBT is a test with excellent reliability when used across multiple raters in different settings.[42] This information adds to the current supporting literature of the usefulness of the SEBT as an assessment tool in clinical and research practice. Establishing excellent interrater reliability with normalized and nonnormalized scores strengthens the evidence for using the SEBT, especially at multiple sites. Decreased core stability, decreased knee muscle strength, and increased knee laxity negatively affected single-limb postural stability ($P < .05$) evident during testing on the SEBT.[54] Deficits in postural stability, evident during posterior-medial and posterior-lateral reach directions of the SEBT are risk factors for ACL injury and continue to exist at a mean of 2.9 years post ACL reconstruction.[44] Components of the SEBT proved to be predictive of lower extremity injury in high school basketball players.[43] Results suggest that the SEBT can be incorporated into preparticipation physical examinations to identify athletes who may be at increased risk for lower extremity injury.[43, 54]

Core Stability and Pelvic Tilt Control.

Ladiera et al.[26] performed a study to investigate the reliability and validity of the double leg lowering maneuver (DLLM) for assessing abdominal muscle strength. The validity was evaluated by comparisons with the Nicholas Hand-Held Dynamometer (NHHD), through abdominal (core) isometric contractions. Twenty-eight volunteers participated and all were tested within the same day by four student physical therapists under the supervision of a licensed physical therapist. Two testers collected data with the NHHD and two other testers collected the DLLM data. Two trials (A and B) were performed for each procedure (NHHD and DLLM) and each trial consisted of three repetitions with a 30 second rest period between each repetition. The average of the three repetitions was the final score for the trial. First, the subjects performed the 3 repetitions for the NHHD (A) with a 1-minute rest before completing the 3 repetitions for the DLLM (A). After 15 minutes, a second trial (NHHD-B and DLLM-B) was completed in the exact order and rest interval as for trial A. Reliability for the DLLM was very high ($r = 0.932$) and validity of DLLM was low ($r = 0.338$ to 0.446).[26]

Krause et al.[25] studied the effects of abdominal muscle performance as measured by the double leg lowering maneuver (DLLM) in healthy males and females between ages 18 and 29 years for use as a component of a clinical assessment of core function. Repeat measurements of the DLLM were conducted to determine reliability and performance standards and to identify variables that may predict performance (gender, age, leg length, height, body mass, physical activity level, regular program of physical activity, regular program of abdominal strengthening, frequency of abdominal strengthening). The ICC for repeated measures of the DLLM was .98. Authors found a gender difference in abdominal muscle performance as measured by the DLLM, with males able to lower their legs on average to 15.4° ± 2.3° from a horizontal reference and females able to lower their legs on average to 36.9° ± 3.4°. A significant difference was found between males and females on performance of the DLLM (*P* < .001). A linear regression model found gender ($r^2 = .22$, *P* = .002) and age ($r^2 = .35$, *P* < .001) to be significant predictors of performance on the DLLM. The negative correlation with age indicates that with increasing age, the measured angle on the DLLM decreases–that is, as age increases, abdominal muscle performance improves.[25]

Zazulak et al.[40] examined the relationship between factors of core stability and prediction of knee injury. Two-hundred and seventy-seven collegiate athletes (140 female and 137 male) were tested for trunk displacement after a sudden force release and prospectively monitored for three years. A quick force release in three directions of isometric trunk exertions was used for assessing the trunk response to sudden unloading. Athletes were placed in a wooden apparatus that was designed for isometric exertions in trunk flexion, extension, and lateral bending. Analysis of variance and multivariate logistic regression identified predictors of risk in athletes who sustained knee injury. Twenty-five athletes (11 female and 14 male) sustained knee injuries over a 3-year period. Trunk displacement was greater in athletes with knee, ligament, and ACL injuries than in uninjured athletes (*P* < .05). Lateral displacement was the strongest predictor of ligament injury (*P* = .009). A logistic regression model, consisting of trunk displacements, proprioception, and history of low back pain, predicted knee ligament injury with 91% sensitivity and 68% specificity (*P* = .001). This model predicted knee, ligament, and ACL injury risk in female athletes with 84%, 89%, and 91% accuracy, but only history of low back pain was a significant predictor of knee ligament injury risk in male athletes.[40]

Wilkerson et al.[22] indicated that core function via static muscular endurance testing predicted knee injury risk in NCAA football players. Eighty-three members of a division I football program were tested on a mandatory preparticipation physical exam the day before the start of preseason. Assessing endurance of the core musculature, the maximum amount of time that a static body position could be maintained against gravity was quantified by four tests that were performed in the same sequence by each player: horizontal back-extension hold, sitting 60° trunk-flexion hold, side-bridge hold, and bilateral wall-sit hold. Aerobic capacity was assessed by the 3-minute step test. An electronic pulse monitor was used to determine recovery heart rate at 15 seconds after completion of the stepping task. Other documented potential predictors of core and lower extremity injury were body mass index (BMI), position category, and level of exposure to potentially injurious circumstances (i.e., games started and games played). An injury was defined as a core or lower extremity strain or sprain that required the attention of an athletic trainer and that limited football participation to any extent for at least 1 day after its occurrence. All injuries were documented throughout the preseason practice period and 11-game season. Receiver operating characteristic (ROC) and logistic regression analyses were used to identify predictive factors that best discriminated injured from uninjured status. The 75th and 50th percentiles were evaluated as alternative cutpoints for division of injury predictors.[22]

A total of 46 core and lower extremity injuries were documented over the course of one season, which represented 7.6 injuries per 1,000 player exposures.[22] At least one core or lower extremity injury was sustained by 39 of the 83 players (47%). Season ending injuries (i.e., ACL tear, syndesmotic ankle sprain, midfoot sprain) were sustained by 3 of the 39 injured players. Players with ≥ 2 of 3 potentially modifiable risk factors related to core function had two times greater risk for injury than those with ≤ 2 factors (95% confidence interval = 1.27, 4.22), and adding a high level of exposure to game conditions increased the injury risk to three times greater (95% confidence interval = 1.95, 4.98). Prediction models that used the 70th and 50th percentile cutpoints yielded results that were very similar to those for the model that used ROC derived cutpoints.[22]

In conclusion, the DLLM is a reliable functional test used to assess core function via pelvic tilt control.[25, 26] Authors conclude that the DLLM is a useful tool to assess pelvic tilt motor control for spine stability, but it is not suitable for assessing core muscle strength.[26] A grading scheme was developed by Kendall[36] which allows for categorization of subjects into five groups based on the degree level achieved during the lowering of the legs and maintenance of pelvic neutral.[36] Krause et al.[25] found that men are able to lower their legs to a position of 15º, therefore being unable to attain a grade of greater than “Good+”. Haladay et al.[41] reported that none of their subjects (healthy, aged 22 to 44 years) were able to attain a grade of greater than “Normal”, even after eight weeks of stabilization exercise. Therefore, the grading system as described by Kendall[36] may reflect an unrealistic level of performance that many populations cannot achieve. Also, the DLLM has some subjectivity and variability in assessing pelvic motion. The ability of clinicians to palpate static musculoskeletal asymmetry has been found to be off by as much as 2.5 cm.[41] Three year prospective analysis determined that athletes with decreased neuromuscular control of the body's core are at increased risk of knee injury. Researchers advocate that athletes be evaluated for deficits in core stability before competition and be prophylactically treated with dynamic neuromuscular training targeted toward their specific deficits in core motor control.[40] Authors conclude that low back dysfunction and suboptimal endurance of the core musculature appear to be important modifiable sports injury risk factors that can be identified on preparticipation screening.[22]

Jump-Landing Mechanics and Lower Limb Control.

Noyes et al.[19] studied the difference in lower limb control by gender and effect of neuromuscular training in female athletes during a drop jump test. The goal of this investigation was to devise a simple video graphic test that would measure the distance between the hips, knees, and ankles in the frontal plane. An additional objective was that the test used standard equipment so that it could be performed outside a formal laboratory. A total of 325 females and 130 males aged 11 to 19 years participated in this study. Athletes played at least one of the following sports: volleyball, basketball, soccer, and gymnastics. The distance between the hips, knees, and ankles were measured during a drop jump test with a standard video camera (two-dimensional). The separation distance between the knees and ankles were normalized by each individual's standing hip separation distance. Sixty-two female athletes completed a neuromuscular training program, and their jump-landing characteristics were reexamined. Isokinetic knee flexion and extension testing (300º/sec) were also conducted before and after training on fifty-four females. Before the video testing, athletes were given a questionnaire for exclusion criteria, including: previous history of lower extremity injury or current symptoms, patellar instability, or visible joint effusion. Also general demographic data were collected including history of athletic participation and current sport/level of participation.[19]

A Sony camcorder with a memory stick was placed on a stand that was 102.24 cm (3 ft.) in height at a distance of 365.76 cm (12 ft.) away from the jump box. The box used was 30.48 cm (12 in) in height and 38.1 cm (15 in) in width. Also, 1-in Velcro circles were placed on each of the four corners of the box and used for measurement calibration. Reflective markers were placed at the greater trochanter and lateral malleolus of both left and right legs. Velcro circles were placed on the center of each patella. A research assistant demonstrated the jump-land sequence to each athlete, and 1 trial was conducted to ensure complete understanding of the test. The athletes were not provided with any verbal instruction regarding how to land or jump, only to land straight in front of the box to be in the correct angle for the camera to record properly. The athletes then performed a jump-land sequence by first stepping off the box, landing, and immediately performing a maximum vertical jump. This sequence was repeated three times.[19]

Statistical analysis using unpaired student *t* tests determined that significant differences between male and female subjects existed for normalized knee and ankle separation distances.[19] Repeated-measures ANOVA was used to determine if significant differences existed between the age categories of 11 to 13, 14 to 16, 17 to 18 years for normalized joint separation distances. Reliability was determined using intraclass correlation coefficients (ICCs) for test-retest, which ranged from 0.94 to 0.96. The ICCs for within test trial of hip, knee, and ankle separation distance were all > 0.90, demonstrating excellent reliability of the 2D video-graphic test and software capturing procedures.[19] There was no correlation between knee and ankle separation distances for each of the jump-land sequences in the female athletes. A knee separation distance of ≤60% was found on pre-landing in 44% of the female athletes; on landing, in 77%; and on takeoff, in 80%. There was no correlation between knee and ankle separation distances for each of the jump-land sequences in the male athletes. A knee separation distance of ≤60% was found on pre-landing in 57% of the male athletes; on landing, in 75%; and on takeoff, in 72%. Female athletes demonstrated significantly higher mean knee and ankle normalized separation distances during the pre-land phase only. After training, female athletes had statistically greater mean normalized knee and ankle separation distances than those of males for all phases of the jump-land sequence. Statistically significant improvements were found in knee flexion peak torque (both dominant and non-dominant legs, $P < .0001$) via isokinetic testing post-neuromuscular training. Statistically significant improvements were noted in the hamstrings-quadriceps ratio for the non-dominant leg, which increased from 73% □ 15% pre-training to 83% □□15% post-training (P = .001).[19]

McLean et al.[55] examined a two-dimensional (2D) video analysis method and potential screening for excessive knee valgus with comparison to the three-dimensional (3D) method. Ten male and ten female NCAA basketball players participated in the study, with 3D knee valgus and 2D frontal plane knee angle quantified during side step, side jump, and shuttle run tasks. Average frontal plane knee angles were larger than corresponding 3D knee valgus angles. Average root mean square (RMS) errors of 1.7º, 1.5º, and 16.0º were found for the 2D analysis for side step, side jump, and shuttle runs respectively. Moderate correlations were found between 2D and 3D peak angle data during side step and side jump, but not for shuttle run. Athletes with large variations in valgus appeared to have stronger correlations between 2D and 3D angle data. Thus authors noted that the 2D method compared to the 'gold standard' 3D motion captures analysis approach appeared to overestimate knee valgus. Also, the authors concluded that the 2D analysis is not identifying knee abduction and is only permitting view of frontal plane knee motion, which may misrepresent axial alignments and joint angles perhaps due to a knee flexion misconception.[55] This observation suggests that a 2D measurement technique should be avoided when precise descriptions of knee valgus magnitudes are necessary. McLean et al.[55] continued to discuss that the potential for a 2D approach as a screening tool, however, should not be discounted. Successful screening of high-risk valgus motions depends on reliable determination of inter-individual differences in peak angle measures. Therefore, if a consistent relation exists between peak 3D dynamic knee valgus and the associated peak frontal plane knee angle, then a 2D approach may afford similar success in determining athletes with the largest valgus motions.[55]

Sigward et al.[39] conducted a study to determine whether normalized knee separation distance (NKSD) is a predictor of knee abduction angles and to assess the influence of lower extremity transverse and frontal plane angles on NKSD during a drop land. Twenty-five healthy female athletes performed a drop-jump maneuver; subsequent data were collected and analyzed, including NKSD, stance width, bilateral average knee and hip transverse and frontal plane angles, and ankle frontal plane angles. Linear regression was used to determine the association between NKSD and bilateral average knee frontal plane angles. Stepwise multiple regressions were used to identify the best predictors of NKSD during the drop land. Results showed a significant positive correlation between bilateral average hip frontal plane angles and NKSD ($r = 0.98$, $P < .001$). A significant negative correlation was found between bilateral average knee frontal-plane angles and NKSD ($r = -0.67$, $P < .001$). Knee transverse plane, hip transverse plane, and ankle frontal plane angles did not correlate significantly with NKSD ($P > .05$). When bilateral average hip and knee frontal plane angles were considered in stepwise multiple regression models that controlled for the influence of stance width, bilateral average hip frontal-plane angle was the only predictor of NKSD, explaining 66% of the variance ($R^2 = 0.66$, $P < .001$). Stance width, entered into the model to account for the effects of foot position, was a significant predictor of NKSD, explaining 31% of the variance ($R^2 = 0.31$, $P = .004$). Together, these variables explained 97% of the variance in NKSD ($R^2 = 0.97$, $P < .001$). The two variables were negatively correlated, indicating that participants with smaller knee separation distances had greater bilateral average knee abduction angles. These results suggest that measures of distance between the knees in the frontal plane may provide some information about knee frontal plane angle during a drop land. Despite the associations between 2D measures of knee separation distance and 3D joint angles, there are limitations to consider when using measures of knee separation distance for clinical analyses. Specifically, a drop jump is a bilateral task, in order to account for the contribution of each limb to knee separation distance; authors averaged joint angles of the right and left limbs. Authors noted that clinically, it would not be possible to determine the individual contribution of each limb to NKSD. Sigward et al. concluded that these measures can assess only overall lower extremity posture and may not be sensitive to assess unilateral deficits.[39]

Barber-Westin et al.[56] investigated the effects of chronological age and gender on neuromuscular indices and strength in 9- to 17-year-old athletes. Researchers tested isokinetic lower extremity strength in 1030 athletes, lower limb alignment during a drop-jump test in 536 athletes, and lower limb symmetry during single-legged hop tests in 324 athletes. Results indicated that knee extension peak torques significantly increased (by

20%) with age; maximum knee strength was noted in girls at age 13 years and in boys at age 14 years (*P* < .001). Although maximum knee flexion strength occurred in boys at age 14 years (*P* < .001), girls had only slight increases from ages 9 to 11 years (*P* = not significant). Boys aged 14 to 17 years had significantly greater normalized isokinetic strength than did age-matched girls. No age or gender effects existed in lower limb alignment on the drop-jump test or limb symmetry on single-legged hop testing. Maximum hamstrings strength was noted in female athletes by age 11 years, compared with age 14 years in male athletes, and a distinct lower limb valgus alignment existed in the majority of all athletes on landing. The absence of a gender difference in lower limb alignment on landing suggests other factors may be responsible for the gender disparity in lower limb injury rates.[56]

Hewett et al.[10] conducted a prospective cohort analysis for the purpose of prescreening high risk athletes, monitoring them over the course of their season and identifying the relationship between injury and injury risk quantified via 3D motion analysis software during a drop jump landing. Investigators hypothesized that female athletes who suffer non-contact ACL injury will demonstrate decreased neuromuscular control and increased knee valgus loads, thus predicting ACL injury risk. There were 205 female adolescent basketball, volleyball, and soccer players who were enrolled in the study during the summer before their seasons began and followed over the course of two fall and one winter seasons (13-months). Dynamic valgus was quantified using 3D biomechanical analyses during three trials of a drop vertical jump. Dynamic valgus was defined as the position or motion, measured in three dimensions, of the distal femur and distal tibia away from the midline of the body. Dynamic valgus consisted of motions and moments of femoral adduction, knee abduction, and ankle eversion.

A total of nine ACL injuries were confirmed (7 during soccer and 2 during basketball) and subsequent groups were developed for statistical analyses (injured vs. uninjured). Logistic regression analysis demonstrated that knee abduction moments and angles (at initial contact and maximum displacement) were significant predictors of ACL injury status (P < .001). Specifically, female knees that suffered ACL injury had 8.4º greater knee abduction angles at initial contact and 7.6º greater at maximum knee flexion than the uninjured knees during landing. Significant correlations between knee abduction angle and peak vertical ground reaction force (GRF) were observed in ACL-injured (r =

.67, $P < .001$) but not in uninjured athletes ($P = .44$). Knee abduction moments which contribute to lower extremity dynamic valgus had a sensitivity of 78% and a specificity of 73% for predicting ACL injury status.[10] Results suggest the value of identifying knee abduction and valgus joint loading in adolescent female athletes during a drop jump maneuver for the purpose of preparticipation ACL injury screening. After identifying injury risk, athletes may benefit from neuromuscular training to correct aberrant high knee joint loading. Authors conclude that there is a need for injury-based prediction measures identified in the clinical setting to reduce limitations of mass participant screening via laboratory testing.[10]

In conclusion, a valgus lower limb alignment upon landing has been shown to be a contributing risk factor for potential noncontact lower extremity injuries.[57] The drop jump video test (DJV) has been shown to measure hip, knee, and ankle separation distances in the frontal plane during a vertical jump maneuver.[55] The DJV has proven to be reliable with high correlation coefficients (ICCs ≥ 0.90).[19] The 2D testing procedure was designed for relatively easy administration by researchers, athletic trainers, therapists, or coaches in any facility using standard equipment and a single camera. The value of the drop jump test has been reported in its ability to assess knee separation distance (KSD) using field-based measurements and objectively quantify hip and knee separation distances for the purpose of identifying knee valgus angles upon landing.[19] The DJV's effectiveness in identifying accurate measures of knee valgus with two-dimensional (2D) video analysis has been questioned by researchers, as frontal plane projection angles may overestimate 2D knee valgus and misrepresent an individuals jump-landing strategy.[55] This test only provides a general indicator of lower limb axial alignment in the frontal plane during a drop-vertical jump maneuver. Researchers have proven the effectiveness of using this tool in combination with other predictor variables for the purpose of identifying potential injury risk and injury risk reduction.[58, 59] Also, the evidence of gender differences between males and females during drop-jump landings is controversial; variation may be contributed to differences in neuromuscular control and fatigue thresholds.[19, 56] However, fatigue induced biomechanical changes of the lower extremity during a drop vertical jump may place an athlete at risk for injury that is not evident during non-fatigued jump landing assessments.

Aerobic Fitness and Fatigue.

Ortiz et al.[18] conducted a study to investigate the effects of metabolic fatigue on knee muscle activation, internal moments, and joint angles during two jump-landing tasks. Fifteen females (mean age: 24.6 ± 2.6 years) participated in athletic jump-landing tasks during fatigue and nonfatigue sessions. Knee kinetics, kinematics, and electromyography (EMG) of quadriceps and hamstrings were recorded during both sessions. The two different jumping tasks consisted of a single-leg drop jump (40 cm box) and a bilateral up-down hopping task on a 20 cm box. The fatigued session included a Wingate anaerobic protocol followed by performance of the two jump landing tasks. Results indicated that participants demonstrated greater knee injury-predisposing factors during the anaerobic fatigue session. However, knee flexion during the up-down task was the only variable resulting in statistical significance ($P = 0.028$).[18]

Augustsson et al.[21] investigated the effects of single-leg hop testing following fatiguing exercise. The first aim was to develop, and to examine the reliability of, a single-leg hop performance under standardized, fatigued conditions. The second aim was to obtain biomechanical information concerning the effect of a quadriceps muscle fatigue protocol on the kinetic and kinematic behavior of the lower extremity during the single-leg hops. Evaluating the first aim, 11 healthy male subjects performed two trials of the single-leg hops under two different test conditions: non-fatigued and following fatiguing exercise, which consisted of unilateral weight machine knee extensions at 80% and 50%, respectively, of 1 repetition maximum (1 RM) strength. Test-retest ICCs ranged from 0.75 to 0.98, indicating moderate to high reliability. Evaluating the second aim, eight healthy male subjects performed the fatiguing exercise protocol. Hip, knee, and ankle kinematics and kinetics were recorded following fatiguing exercise while subjects performed single-leg hops. Results indicated that hip moments and ground reaction forces were lower for the fatigued hop conditions compared to the non-fatigued condition upon single-leg hop landing ($P < .05$).[21]

Dalton et al.[17] conducted a case-control study comparing dynamic balance, vertical jump height, gluteus medius muscle activation, and hip muscle strength after aerobic exercise in people with ACL-reconstructed knees. Seventeen recreationally active subjects who had confirmed unilateral ACL-reconstruction (ACL-R) were matched with seventeen healthy control subjects. All subjects were evaluated using a pre-test, post-test design and comparison was made using four dependent variables: (1) dynamic balance, measured via the SEBT, (2) gluteus medius EMG signal measured at max reach distance during the SEBT, (3) max single-leg vertical jump height, and (4) max isometric force output measured by an isokinetic dynamometer on the hip extensors, abductors, and external rotators. Between pre and post testing, subjects performed 20 minutes of graded aerobic exercise on a treadmill, using the Balke protocol.[17] Both groups demonstrated deficits in neuromuscular control. The ACL-R group experienced a greater reduction in hip extensor strength as well as greater deficits in dynamic balance after a bout of graded aerobic exercise ($P < .05$).[17]

Ostenberg et al.[9] performed a prospective investigation for the purpose of registering all sports injuries during one season and correlate the preseason results of isokinetic muscle strength, functional performance, aerobic capacity and physical characteristics to the distribution of injuries. A total of 123 female soccer players from eight teams of different playing levels were followed during one season. Generalized joint laxity via the modified Beighton method and Body Mass Index (BMI) were measured. Following physical measures, isokinetic knee muscle strength were recorded at 60 and 180º/sec using a Cybex Dynamometer 325. Next, functional performance tests were conducted, including the single hop for distance, vertical jump, and square hop tests. Aerobic capacity was clinically evaluated via the multi-stage fitness test (MSFT). During the season (7 months), all injuries resulting in absence from one practice/game or more were registered. Forty-seven of the 123 players sustained altogether 65 injuries. The total injury rate was 14.3 per 1,000 game hours and 3.7 per 1000 practice hours. The knee (26%) was the most commonly injured region followed by the foot and ankle (11-12%). Thirty-nine (60%) of the injuries occurred after 60 min or more of practice or game time. A Chi-square test revealed that the moderate and major injuries occurred later during practice/game than the minor injuries ($P = .002$). Significant risk factors for injuries were an increased general joint laxity ($P < .001$), a high performance in the functional test square hop ($P = .002$), and an age over 25 years ($P = .01$). The injury rate was not different compared to male soccer players.[9]

Konopka et al.[46] conducted a review of literature analysis for the purposes of investigating the anabolic potential of aerobic exercise training and to discuss the subcellular mechanisms to support muscle growth after chronic aerobic exercise. Authors demonstrated alterations in skeletal muscle molecular regulation and protein metabolism that are conducive for increased myofiber and whole-muscle size after aerobic exercise training in sedentary individuals. Results suggest that cross-talk between pathways regulating mitochondrial homeostasis and skeletal muscle protein metabolism may play a role in the ability of aerobic exercise to stimulate skeletal muscle hypertrophy. These data are contrary to current exercise training and rehabilitation mentalities, but are in correspondence with previous literature relating aerobic fatigue to decreases in strength and functional performance measures.[17, 21] Konopka and colleagues provide considerable evidence to support that aerobic exercise training can produce skeletal muscle hypertrophy and thus should be warranted in the prescription of exercise for athletes who participate in anaerobic and aerobic demanding activity.[46]

In conclusion, fatigue (anaerobic and aerobic) has been shown to adversely alter lower extremity landing biomechanics during single leg hopping assessments with joint positions that specifically mimic knee injury mechanisms.[18, 21] Aerobic exercise induced fatigue resulted in decreased lower limb strength and dynamic balance in healthy and ACL-reconstructed patients.[17] It has been reported that a high percentage (60%) of injuries occur during the latter end of a game or practice and the risk of suffering moderate to severe injuries increases compared to minor injuries.[9] Both aerobic and anaerobic athletic tasks induce metabolic fatigue and both energy systems are required in most contact/collision sports; thus early onset of metabolic fatigue may increase risk for lower extremity injury during athletic contests.[9, 18] The ability to identify and categorize athletes based on aerobic endurance levels measured via analysis of maximal oxygen uptake (VO_2 max) has been of value to researchers and clinicians. However, due to the restraints and practicality of laboratory testing, researchers have developed field-based tests and prediction equations to estimate VO_2 max from the clinical setting.

The Multi-Stage Fitness Test.

Leger et al.[28] conducted the multi-stage fitness test (MSFT) on boys and girls aged 8 to 19 years of age with three different experimental procedures. The first set of experiments involved 188 boys and girls performing the MSFT individually up to their volitional limit. Their VO_2 max was determined by retro-extrapolating the O_2 recovery curve at time zero of recovery at the end of the MSFT. The second set of experiments involved 53 men and 24 women below (n = 38) and above (n = 39) thirty-five years old had their VO_2 max measured with the retro-extrapolation method at the end of the MSFT. The third set of experiments involved 139 boys and girls aged 6 to 16 years and 81 men and women aged 20 to 45 years who performed the MSFT twice, one week apart, in order to determine the test re-test reliability. Groups of 10 to 20 subjects performed the test together. Validity of the MSFT was assessed with multiple regression analysis and reliability was assessed with simple regression analysis and paired *t*-tests. Results indicated the MSFT was reliable in both children ($r = 0.89$) and adults ($r = 0.95$). No significant difference ($P > 0.05$) was found between tests and re-tests. Children's VO_2 max could be predicted from the maximal aerobic shuttle running speed and age with a correlation of 0.71 and a standard error of estimate of 5.9 ml kg^{-1} min^{-1}. Sex, height, and weight were not significant predictors. Adults VO_2 max was only related to maximal speed ($r = 0.90$), along with a standard error of estimate of 4.7 ml kg^{-1} min^{-1}. Similar measurements for adults indicated that the same equation could be used keeping age constant at 18 (r = 0.90, n = 77 men and women 18-50 years). Test-retest reliability coefficients were 0.89 for children (139 boys and girls 6-16 years old) and 0.95 for adults (81 men and women, 20-45 years old). The lower validity of the MSFT in children as compared to adults might have resulted from large inter-individual variations in the biological age, since chronological age is used as a predicting variable.[28]

Ramsbottom et al.[38] reexamined the validity of the MSFT to estimate VO_2 max reported by Leger et al.[28] one year later. Seventy-four subjects (36 men, 38 women) aged 19 to 36 years old performed, in random order, an uphill treadmill test to determine VO_2 max directly, a 20 m shuttle run test (MSFT) and a 5 kilometer (km) time trial. An interval of three days elapsed between each test. Running ability was described as the final level attained on the MSFT and as time on the 5 km run. Maximal oxygen uptake values, measured directly, were 58.5 ± 7.0 and 47.4 ± 6.1 ml kg^{-1} min^{-1} for the men and women respectively (mean ± SD, $P < 0.01$). The levels attained on the MSFT were 12.6 ± 1.5 for men and 9.6 ± 1.8 for women ($P < 0.01$). The correlation between VO_2 max and shuttle level was r = 0.92. The correlation between VO_2 max and the 5 km run was -0.94 and -0.96 between both field tests.

Sproule et al.[47] investigated the results of the MSFT compared with direct measurements of maximal oxygen uptake in an Asian population. The purpose of this study was to evaluate the validity of predicting the VO_2 max of Asian adults from performance on the MSFT in a hot humid environment amongst a secondary school population in Singapore. Twenty subjects (16 male, 4 female) aged 21 to 35 all of whom were physical education students, were assessed directly using laboratory treadmill running to determine VO_2 max. The indirect estimation of VO_2 max was obtained using a modified form of the Leger and Lambert 20 m multistage shuttle run test.[28] Heart rates were recorded throughout both tests. Pearson product moment correlations confirmed test-retest reliability for both direct and indirect measurements (r = 0.90 and r = 0.91 respectively). No differences were found between the maximal heart rate responses of the subjects for the direct and indirect tests. Seventy-five percent of the subjects had a lower predicted VO_2 max value ($P < 0.01$) compared with results gained by direct measurements when the Ramsbottom[38] norms for the MSFT were used. Authors noted that the reasons for this difference could be due to the different racial groups used as subjects, the climatic conditions in Singapore, or the small sample size.[47]

Flouris et al.[48] developed a new prediction algorithm for the MSFT using data collection via portable indirect calorimetry and statistical procedures, which accounted for within-subject observation dependency. The efficacy of both the original and the novel models were assessed in predicting standard treadmill VO_2 max. One hundred and ten males (mean age 21.6) volunteered for this study, and subsequently divided into model (n = 40) and validation (n = 70) groups. All subjects underwent a treadmill VO_2 max assessment and performed the MSFT in an indoor rubber floored gymnasium within a 14-day period. A modified Bruce treadmill test (TT) to exhaustion was used when obtaining direct VO_2 max measurements. Unlike the validation group, subjects in the model group were subjected to VO_2 max assessment while performing the MSFT using a portable gas analyzer. Energy cost (EC) in kilocalories (kcal) was calculated for each individual minute/stage as the product of mean VO_2 by the corresponding caloric equivalent. Results revealed significant energy cost variance (EC_v) differences between

TT and the MSFT ($P < 0.001$). Energy cost variance correlated significantly with subject height ($r = 0.94$) and was a significant predictor of VO_2 max differences between TT and MSFT ($r^2 = 0.25$). Predicted VO_2 max values correlated with directly measured MSFT VO_2 max at $r = 0.96$ ($P < 0.001$). Analysis of variance (ANOVA) detected no mean difference ($P < 0.05$) between predicted and measured values. Results from the newly developed model demonstrated increased accuracy in predicting VO_2 max and a minimized standard error of estimate (1.9 ml kg^{-1} min^{-1}) compared to the original equations (4.4 and 2.7 ml kg^{-1} min^{-1}).[48]

Paradisis et al.[60] investigated the validity and suitability of predicting both VO_2 max and the velocity at which VO_2 max occurs (vVO_2max) using the MSFT in forty-eight collegiate physical education students. Subjects performed a laboratory-based continuous treadmill test to determine VO_2 max and vVO_2max, followed by completion of the MSFT, separated by a three day interval. Other variables were also recorded, including percent body fat (via a Harpenden skinfold caliper), heart rate (HR), and blood lactate (via fingertip blood samples, taken within 5 minutes of completing each test). Statistically significant correlations were found between the number of shuttles in the MSFT and treadmill VO_2 max ($r = 0.87$, $p < 0.05$) as well as vVO_2max ($r = 0.93$, $p < 0.05$). No significant differences were found between laboratory measured and predicted values of VO_2 max (49.98 ± 8.33 and 49.97 ± 7.17 ml/kg^{-1}/min^{-1}), vVO_2max, HR [(at VO_2max)(14.52 ± 2.65 and 14.51 ± 2.43 km/h^{-1})] and blood lactate levels [(at VO_2max)(12.05 ± 1.96 and 12.09 ± 1.90 mmol/L^{-1})].[60]

Palickza et al.[61] reported on the validity of the MSFT as both a field-based test used to predict VO_2 max and a predictor of competitive performance in a 10km race. Direct measurements of maximal oxygen uptake were recorded during a graded maximal exertion test on a treadmill in the laboratory setting. Analysis using Pearson’s Product Moment Coefficient revealed high correlations between variables ($r = 0.93$) and a standard error of estimate (SEE) of 3.91. Relationship between MSFT scores and results of the 10km race resulted in an ‘r’ value of -0.93 and an SEE value of 2.89.[61]

In conclusion, the multi-stage fitness test (MSFT) has been reported to have direct relationships corresponding to actual measurements of VO_2 max using the gold standard laboratory approach.[28] High reliability ranging from .89 to .91 has been reported using the same procedures and regression equations.[28, 47] Maximal oxygen uptake values can be predicted from the level attained on the MSFT with an standard error of estimation (SEE) ranging from 3.5 to 5.9 ml kg^{-1} min^{-1}.[28, 38] Multi-stage fitness test values have been shown to correlate to VO_2 max with predicted *r* values ranging from .71 to .93.[28, 38, 60, 61] Flouris and colleagues developed a new model which increased the accuracy of prediction and correlation of direct measured VO_2 max with a SEE of 1.9 ml kg^{-1} min^{-1} and an *r* value of .96.[48] The MSFT is recommended by the American College of Sports Medicine as a reliable and valid method to estimate VO_2 max.[62] Normative data have been developed according to age and gender for analysis of aerobic fitness between populations; thus the MSFT can be used to categorize subjects according to fitness level and for group (within-subjects) comparison.[28, 38, 62] A key advantage of the MSFT is the application of the same protocol for all age groups making it possible for longitudinal or cross-sectional comparisons.[28] Subsequently, authors advocate the utilization of this functional test for assessment of aerobic capacity adaptations pre-and-post training interventions.

Neuromuscular Training Interventions

Noyes and colleagues conducted two sport-specific neuromuscular training studies with high risk populations and found significant decrease in potential lower extremity injury risk and an increase in potential performance.[29, 30] Both studies used the same neuromuscular training protocol as well as performance indices to evaluate the effectiveness of the training program as well as the ability of the objective assessments to identify improvement in training. Subjects were high school aged female athletes (soccer and basketball) who participated in preseason conditioning programs three days/week for 90 to 120 minutes and lasted 6-weeks in duration. The conditioning program consisted of a dynamic warm-up, jump training, strength training, and flexibility training with exercise from a previously published ACL injury prevention program along with new exercise and drills to improve speed, agility, overall strength, and aerobic conditioning. A battery of tests were conducted to determine the effectiveness of this training program in improving lower limb alignment on a drop-jump test, estimated VO_2 max (via the MSFT), vertical jump height, and sprinting speed (via either 18-m or 37-m sprint test).

Data from the drop jump video test were divided into three categories for analysis: ≤ 60% normalized knee separation distance (according to hip separation distance), 61 to 80%, and > 80%.[29, 30]

Noyes et al.[29] investigated potential injury prevention and performance enhancement on 57 female basketball players (aged 14 to 17) who participated in preseason neuromuscular and performance training. Statistically significant increases were found between pretrained and posttrained test sessions using the drop-jump video test in analyzing mean absolute knee separation distance (KSD) ($p < 0.0001$), mean normalized KSD ($p < 0.0001$), and in the distribution of the subjects in the normalized KSD categories ($p < 0.0001$). Improvement in normalized KSD was demonstrated in 91% of the subjects.[29] Significant improvement was found in the mean estimated VO_2 max score ($p < 0.0001$) and in the difference among the distribution of subjects in the categories between pretrain and postrain sessions ($p < 0.0001$). Improvement in estimated VO_2 max score was demonstrated in 89% of the subjects. A significant improvement was found in vertical jump height ($p < 0.0001$), as 70% of the subjects increased their scores but the effect size was small (0.09). There was no significant improvement in the 18-m sprint test.[29]

Noyes et al. [30] investigated potential injury prevention and performance enhancement on a total of 62 female soccer players (aged 14 to 17) who participated in a preseason conditioning program with test assessments at 6-weeks. Significant increases were found in the mean normalized KSD between pretrained and posttrained test sessions ($p < 0.0001$), indicating a more neutral lower limb alignment on landing. Before training, the normalized KSD was ≤ 60% in 62% of the subjects and 61 to 80% in 38% of the subjects. After training, a significant improvement was detected, as normalized KSD of ≤ 60% (high risk) remained in only 4% of subjects and 61 to 80% in 96% of subjects ($p < 0.0001$). Improvements were shown in absolute KSD in 87% of subjects, in ankle separation distance in 84%, and in normalized KSD in 90% of subjects. Sixty-nine percent of subjects showed increased estimated VO_2 max levels via improvement in the MSFT from pretrain to posttrain sessions.[30]

Barber-Westin et al.[63] performed a neuromuscular training intervention study on sixteen adolescent female high-school volleyball players. The purpose of this research study was to determine if immediate improvements in overall lower limb alignment in adolescent female athletes on a drop-jump video test after a 6-week neuromuscular retraining program would be retained up to one year later. All subjects underwent the drop-jump video test one week before the neuromuscular training program was initiated. Subjects then participated in a supervised training program three days/week for 90 to 120 minutes and lasted 6-weeks in duration. The sessions consisted of a dynamic warm-up, jump training, strength training, speed and agility drills specific for volleyball, and flexibility. The athletes then underwent the drop-jump video test within 7 days of completing the training program and then 3 and 12 months after training. The absolute centimeters of separation distance between the right and left hips, knees, and ankles were measured and then normalized according to the hip separation distance. Researchers compared the distribution of subjects who had ≤ 60% normalized knee separation distance, 61-80%, and > 80% during preland, landing, and takeoff. The authors suggested that 60% or less represented a distinctly abnormal lower limb valgus alignment position. The ICCs for test-retest of hip separation distance demonstrated high reliability (preland, 0.96; landing, 0.94; takeoff, 0.94). The ICCs for within-test trials of the hip, knee, and ankle separation distances were all ≥ 90%, demonstrating excellent reliability of the video graphic test and software capturing procedures. Significant improvements were found in the mean normalized knee separation distances between the pre and post-trained values for all test sessions ($p < 0.01$). Immediately after training, 11 athletes (69%) displayed significant improvements in their lower limb alignment that were retained 12 months later. Before training, 75% of the subjects had ≤ 60% knee separation distance, indicating poor overall lower limb control during a drop vertical jump maneuver. One year later, only 19% were in this category. The five athletes that failed to improve or retain their initial improvements in normalized knee separation distances were encouraged to continue neuromuscular and strength training if possible within the allowance of their volleyball training and season participation.[63]

In conclusion, Noyes and colleagues determined from two investigations that sport specific training for ACL injury prevention, correction of neuromuscular deficiencies, and improvement of athletic performance indices can be accomplished via a 6-week supervised training program.[29, 30] Researchers have shown that the DJV test may be implemented as part of preparticipation screening for identifying potential injury risk due to improper jump landing technique or neuromuscular deficiencies.[29, 30, 63] The MSFT shows high test re-test reliability (ICCs ≥ 90) and the ability to identify aerobic endurance improvements after 6-week training programs.[29, 30] Neuromuscular interventions have been shown to reduce lower extremity injury incidence via training modifiable neuromuscular risk factors.[34, 64, 65] The ability to accurately assess these injury risk factors from a clinical setting is imperative. Research advocates clinician-friendly criteria as part of the critical adoption for preparticipation functional screening methods.

Physical Performance Testing & Functional Movement Screening

Hegedus et al.[32, 33] produced a series of manuscripts that summarized physical performance tests (PPTs) of the lower extremities, and that examined the methodological quality of current research and the quality of measurement properties of each PPT. Authors operationally defined PPTs as measures that assess components of sport function (strength, power, agility), determine readiness for return to sport, or predict injury of the lower extremity; and as measures that can be performed field side, courtside, or in a gym with affordable, portable and readily available equipment. The most common PPTs reportedly studied were: single hop for distance, triple hop for distance, 6 meter timed hop, crossover hop for distance, single leg vertical jump, single leg squat, figure of eight run, triple jump, star excursion balance test (SEBT), sprint test (40 yards), shuttle run, vertical leap, T-agility, and multi-stage fitness test. Results indicated that the SEBT has ‘good’ reliability, ‘excellent’ criterion validity, and ‘poor to good’ hypothesis testing. There was moderate evidence that the SEBT is able to detect differences between unstable and normal ankles within and between subjects. There was strong evidence that the modified 3-direction SEBT is able to predict injury. Both a composite reach score difference of less than 94% and an anterior reach difference of 4 cm or greater is associated with increased injury risk. There was moderate evidence of the construct validity for the triple hop for distance, which provides different results between athletes who have ankle instability and those who do not. There was strong evidence that this PPT was not a predictor of injury.[32, 33]

Brumitt et al.[31] performed a prospective cohort study to determine the ability of the standing long jump (SLJ) test, the single-leg hop (SLH) for distance test, and the lower extremity functional test (LEFT) as preseason screening tools to identify collegiate athletes who may be at increased risk for a time-loss sports-related low back or lower extremity injury. A total of 193 Division III athletes from 15 university teams (110 females, age 19.1 ± 1.1 years; 83 males, age 19.5 ± 1.3 years) were tested prior to their sports seasons. Athletes performed the functional tests in the following sequence: SLJ, SLH, LEFT. The athletes were then prospectively followed during their sports season for occurrence of low back or lower extremity injury. Forty-six athletes (females = 27; males = 19) experienced a total of 63 time-loss injuries during the study. The results indicated that 1) female athletes with side-to-side asymmetry between SLH distances (>10%) had a four-fold increase for a foot or ankle injury, 2) male athletes with SLH distances (either leg) at least 75% of their height had at least a 3-fold increase for a low back or lower extremity injury, 3) female athletes who completed the LEFT in 118 seconds or more were six times more likely to sustain a thigh or knee injury, and 4) male athletes who completed the LEFT in 100 seconds or less were more likely to experience a time-loss injury to the low back or lower extremity than slower male athletes. The SLJ was not associated with increased injury risk for either female or male athletes in this sample.[31]

Smith et al.[66] investigated inter-rater and intra-rater reliability of the Functional Movement Screen™ (FMS) with real-time administration with raters of different educational background and experience. The FMS was assessed with real-time administration in 20 healthy injury-free men (n = 10) and women (n = 10) and included a certified FMS rater for comparison of other raters. Raters (n = 4) with varying degrees of FMS experience and educational levels underwent a two-hour FMS training session. Subjects (n = 19) were rated during two sessions, one week apart, using standard FMS protocol and equipment and were subjectively scored on a series of seven fundamental movements using a four-point ordinal scale (3–0) to obtain a total score (21–0). Inter-rater reliability was good for session one (ICC = 0.89) and for session two (ICC = 0.87).

The individual FMS movements showed hurdle step as the least reliable (ICC = 0.30 for session one and 0.35 for session two), whereas the most reliable was shoulder mobility (ICC = 0.98 for session 1 and 0.96 for session 2). Intra-rater reliability was good for all raters (ICC = 0.81–0.91), with similar ICCs regardless of education or previous experience with FMS. The results showed that raters with varying degrees of experience could consistently score the FMS after a 2-hour training session. Intra-rater reliability was not increased with FMS certification.[66]

Kiesel et al.[50] investigated the relationship between professional football players' score on the FMS and the likelihood of serious injury. Prior to the start of the season, 46 professional football players were tested by the team's strength and conditioning specialist (CSCS) evaluating the FMS as an injury screening physical performance test. The composite score was analyzed retrospectively for each player. A serious injury was defined as any injury that placed the athlete on the injured reserve for at least three weeks. The mean ± SD FMS score (highest possible score is 21) for all subjects was 16.9 ± 3.0. The mean score for those who suffered an injury was 14.3 ± 2.3 and 17.4 ± 3.1 for those who were not injured. A t-test revealed a significant difference between the mean scores of those injured and those who were not injured ($t = 5.62$; $P < 0.05$). A score of 14 or less on the FMS was positive to predict serious injury with specificity of 0.91 and sensitivity of 0.54. The odds ratio was 11.67, positive likelihood ratio was 5.92, and negative likelihood ratio was 0.51. The odds ratio of 11.67 can be interpreted as a player having an eleven-fold increased chance of injury when their FMS score is 14 or less when compared to a player whose score was greater than 14 at the start of the season. The post-test probability was calculated to be 0.51. That is to say, if an athlete's score on the FMS was 14 or less, their probability of suffering a serious injury increased from 15% (pre-test probability of 0.15) to 51% (post-test probability of 0.51; CI 95= 0.25-0.76).[50]

Chorba et al.[51] sought to determine if compensatory movement patterns predispose female collegiate athletes to injury, and if the Functional Movement Screening (FMS) could be used to predict injuries in this population. Composite FMS scores were measured for 38 NCAA Division II female collegiate athletes (mean age 19.24 ± 1.20 years) before the start of their respective fall and winter sport seasons (soccer, volleyball, and basketball). Seven athletes reported a previous history of anterior cruciate ligament reconstruction (ACL-R). Injuries sustained while participating in sport activities were recorded throughout the seasons. Inter-rater reliability was determined between the leading investigator and an independent investigator (both licensed physical therapists). Intraclass correlation coefficients (ICCs) ranged from 0.77 to 0.97 for individual tests of the FMS, while an ICC of 0.98 was calculated for the composite FMS score. The mean ± SD FMS score for all subjects was 14.3 ± 1.77 (maximum score of 21). The mean FMS score for the injured group was 13.9 ± 2.12, while those who did not sustain an injury had a mean score of 14.7 ± 1.29. Athletes with a composite FMS score of ≤ 14 (n = 16), 68.75% of those individuals sustained an injury throughout their respective competitive season. Additionally, 81.82% of subjects who scored at or below 13 and 48.28% of subjects who scored at or below 15 sustained injuries. A strong correlation existed between injury and FMS score ($r = 0.761$, $P = 0.021$). Linear regression analysis for the data from all subjects (n = 38) produced results ($P = 0.0748$, $r = -0.7676$, $r^2 = 0.5892$) that did demonstrate a statistically significant relationship between FMS score and risk of injury. Consequently, a lower score on the FMS was significantly associated with injury, with 69% of those scoring 14 or less sustaining a lower extremity injury, and experiencing a four-fold increase in injury risk.[51]

Letafatkar et al.[52] investigated the relationship between the FMS score and history of injury, and evaluated which active students are prone to injury. One hundred physically active (50 females and 50 males) students, mean age 22.56 ± 2.99 years who participated in soccer, handball, and basketball for at least for 5 years were recruited. Subjects had no recent (<6 weeks) history of musculoskeletal injury. The data were collected by two members of the research team, both licensed physical therapists. The composite score for all seven movements of the FMS was recorded and then compared with the injury documentation and tracking of the lower extremity that occurred throughout the season, which was achieved by the teams' specific athletic trainer and sports medicine staff. The average inter-tester reliability between testers was high for FMS tests (ICC = .877 – .932). The inter-rater reliability (ICC) of the composite score for both testers was .92. Thirty-five subjects suffered an acute lower extremity (ankle = 20, knee = 15) injury in practice or competition. For all subjects, a cut-off score of 17 was used that maximized sensitivity (0.645) and specificity (0.780). An overall odds ratio was calculated at 4.70, meaning that an athlete had an approximately 4.7 time greater chance of suffering a lower extremity injury during a regular season by scoring less than 17 on the FMS. There was a statistically significant difference between the pre-season FMS scores of the injured and the non-injured groups (*P* = .005). A one-way ANOVA revealed a statistically significant difference between the ankle injury group, knee injury group, and no injury group (*P* = .030). The Bonfferoni post hoc testing demonstrated that the differences existed between the ankle injury group and no injury group (*P* = .021), as well as between the knee injury group and no injury group (*P* =. 030); but not between the ankle injury group and knee injury group (*P* = .101).[52]

Lisman et al.[23] investigated associations between injuries and individual components of the Marine Corps physical fitness test (PFT), self-reported exercise and previous injury history, and Functional Movement Screen (FMS) scores. A cohort of 874 men (mean age: 22.4 ± 2.7 years) enrolled in either 6 week (n = 447) or 10 week (n = 427) of Marine Corps officer candidate training were recruited. Subjects completed an exercise history questionnaire, underwent an FMS during medical in-processing, and completed the standardized PFT (pull-ups, abdominal crunch, and 3-mile run) within one week of training. Injury data were gathered throughout training from medical records and classified into overuse, traumatic, and any injury. Results indicated that the three-mile run time (RT) was the only PFT component predictive of injury. Candidates with RT ≥ 20.5 min were 1.7 times (95% confidence interval = 1.29–2.31, $P < 0.001$) more likely to experience an injury compared with those with RT < 20.5 min. Prior injury, frequency of general exercise and sport participation, and length of running history were predictive of any, overuse, and traumatic injuries, respectively. Combining slow RT and low FMS scores (≤ 14) increased the predictive value across all injury classifications: candidates scoring poorly on both tests were 4.2 times more likely to experience an injury. The pull-up to exhaustion test was related to four of the seven FMS tests and the only PFT test positively related to total FMS score, although correlations were generally low ($r \leq 0.11$).[23]

In conclusion, a physical performance test (PPT) is a low technology measure that can be performed by everyone from coaches to healthcare professionals to examine components of sport (strength, power, agility) through multi-joint movements.[32, 33]

Clinically, PPTs are used, in the lower extremity especially, after injury or surgery to evaluate symmetry and readiness for return to play. Physical performance tests are also used as preseason screening examinations to discern deficiencies that may lead to injury.[32, 33] Similarly, research has found that preparticipation functional tests can identify increased risk of low back and lower extremity injury in collegiate athletes.[31] Functional tests require minimal personnel, are quick to administer, and do not require special equipment.[31] However, no such combination of functional tests has been reported, except for the previously established FMS™. The Functional Movement Screen (FMS) was developed to qualitatively screen basic movement patterns used in athletics to assess intrinsic risk for injury based on the ability to perform certain movements with or without compensation.[66] Overall, the FMS has shown excellent inter- and intra-rater reliability for composite scores with ICCs ranging from .81 to .97.[50-52] However, reliability of individual tests varied widely, with ICCs ranging from .30 to .98.[66] The FMS has been described as an injury predictor with a score ≤ 14 associated with an increased risk of serious injury in professional football players[50], lower extremity injury in collegiate female athletes[51], and acute lower extremity injury among college-aged physically active students[52]. Low FMS score (≤ 14) combined with a poor aerobic fitness measure (3 mile run time) significantly increased the injury predictive value in military candidates.[23] Subsequently, a combination of functional movement tests with an aerobic fitness test may warrant success in clinical identification of sports-related injury risk.

Conclusion

An estimated 30 million children aged 5 to 18 years participate in organized sports programs in the U.S. Unfortunately, approximately one third of these children sustain sports injuries requiring medical treatment, with the ankle and knee being the most commonly injured areas.[56] When considering the growing population of young athletes along with the important physical and social benefits of sport participation, reducing sport injury rates should be a priority. Sports injury mechanisms are multi-dimensional; therefore, preparticipation screening protocols along with injury prevention schemes should incorporate assessment of multiple dynamic risk factors that have been linked to injury directly or via neuromuscular association. Sport-specific studies identifying activities with high injury risk can help ATCs and strength/conditioning coaches develop targeted training techniques to lower injury rates.[3] Clinical quantification of basic movement patterns used in athletics to assess intrinsic risk for injury and subsequent injury prevention via neuromuscular training can be a vital step in bridging the gap between the biomechanics laboratory and the athlete.[6]

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APPENDIX A: Data Collection Form

University of Hawai'i Kinesiology & Rehabilitation Science

Lower Extremity Grading System

Name: ______________________________ Date: ____________
Testing group: __________ ID#: ______________
Height: ___________ Weight: ___________
DOB: ___________

LOWER LIMB STRENGTH & POWER

Triple Hop for Distance

Right *Trial 1______ Trial 2______ Trial 3______

Left *Trial 1______ Trial 2______ Trial 3______

Greatest R dist. (A_R) ___________ (cm) **Greatest L dist.** (A_L) ____________ (cm)

DYNAMIC BALANCE

Star Excursion Balance Test

RIGHT **LEFT**

Anterior *Trial 1______ Trial 2______ Trial 3______*Trial 1______ Trial 2_____ Trial 3______
Posteromedial *Trial 1______ Trial 2______ Trial 3______*Trial 1______ Trial 2______ Trial 3______
Posterolateral *Trial 1______ Trial 2______ Trial 3______*Trial 1______ Trial 2______ Trial 3______

Greatest	R reach distance	MAXD (B_R)	L reach distance	MAXD (B_L)
Anterior				
Posteromedial				
Posterolateral				

MAXD = [reach distance (cm) / leg length (cm)] x 100

CORE STABILITY

Double Leg Lowering Maneuver

*Trial 1______ Trial 2______ Trial 3______ Avg. Angle (C): _______ °

Leg length: R_________ L ________ (cm)

JUMP MECHANICS & LOWER LIMB CONTROL

Drop-Jump Video Test

*Trial1______ Trial 2______ Trial 3______

KSD/HSD (D) = _____%

Avg. KSD = _______ (cm)

AEROBIC FITNESS

Multi-Stage Fitness test

Level _________

Shuttle _________ Est. VO_2 max (F): ___________ml/kg • min^{-1}

APPENDIX B: Recruitment Flyer

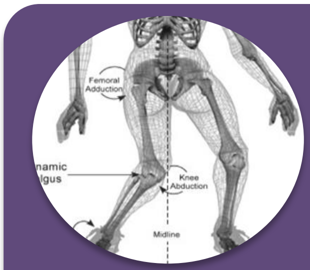
The University of Hawai'i is conducting a research study:

Quantification of Neuromuscular Quality and Risk of Lower Extremity Injury in Adolescent Athletes

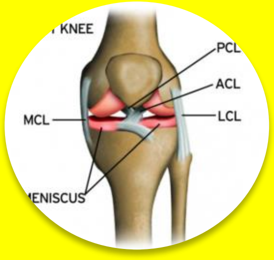
Do you qualify for this study?

You may be able to participate if you:

- Currently play Intermediate, JV, or Varsity sports
- Sports include: **Boys & Girls** Basketball, Volleyball, & Soccer
- Have a completed, up-to-date sports physical



The purpose of this research project is to investigate whether a group of functional tests administered before competition can identify injury risk in individual's who may be at-risk for knee injury, specifically to the Anterior Cruciate Ligament or ACL



The ACL is a ligament inside the knee that connects the joints of the thigh and lower limb. These ligaments control the back and forth motion of the knee and rotational movements. The ACL is one of the most commonly injured knee ligaments and often requires surgery and a long rehabilitation process to allow proper healing and full recovery

Athletes who participate in high demand sports such as basketball, soccer, and volleyball seem to be at higher risk for knee injury. Most injuries are noncontact in nature and usually occur during high risk movements such as: changing direction rapidly, stopping suddenly, slowing down while running, and landing from a jump incorrectly

- There will be **2** study visit's located in the gymnasium of your school
- Your active participation will take approximately **60- 90** minutes
- Study visits will be separated by gender (ALL age groups tested together)

To learn more about this study, please contact:

Nick DePhillipo, ATC, CSCS__Office: 808.956.7421__Email: uhkist@gmail.com

The principle researchers for this study are Nick DePhillipo & Joseph Smith, MS, ATC at the Department of Kinesiology and Rehabilitation Science

APPENDIX C: IRB Consent Form

Consent Form for Participation in a Research Study University of Hawaii at Manoa

Department of Kinesiology and Rehabilitation Science, University of Hawaii at Manoa
1337 Lower Campus Road, PE/A Complex Rm. 231, Honolulu, HI 96822
Phone: 808-956-7606

TITLE: *The Knee Injury Screening Tool: Quantification of Neuromuscular Quality & Risk for Knee Injury in Adolescent Athletes*

Description of the Research and Participation

Your son/daughter/guardian has been invited to participate in a research study. This study will be conducted by Nicholas DePhillipo, ATC, CSCS, Joseph Smith, MS, ATC, Iris F. Kimura, PhD, ATC, PT, Timothy Cuddeback, ATC, CSCS, Adam Slabicki, ATC. The purpose of this study is to assess risk factors for knee injuries. Athletes in sports such as volleyball, basketball, and soccer are at risk for knee injury. Most injuries are not caused by contact with another player. They usually occur by changing direction, stopping suddenly, or landing from a jump.

The Knee Injury Screening Tool (KIST) is made up of five athletic tests. These tests will measure your child's/guardian's balance, jumping, strength, and endurance. These qualities are important in playing sports safely. The tests are listed below.

1) Triple hop test
    a. Your child/guardian will stand on a single leg and hop three times forward as far as possible. The distance will be measured.
2) Single leg balance test
    a. Your child/guardian will stand on one leg and reach as far as possible in three directions while maintaining balance. The distance they can reach maximally will be measured.
3) Abdominal strength
    a. Your child/guardian will lie on their back on a table. Then your child/guardian will raise their legs together and slowly lower them towards the table. The angle of the legs will be recorded.
4) Jumping test
    a. Your child/guardian will step off a 1-foot box and jump as high as possible. They will be video taped. Their jump landing will be measured.
5) Fitness test
    a. Your child/guardian will run back and forth between 2 lines 20-meters apart. An audio recording will beep to keep them on pace. They will run until exhaustion or until they cannot maintain pace.

Study Population & Safety

Your child/guardian is being asked to participate in this study because they are a healthy student-athlete who plays volleyball, basketball, or soccer. Vulnerable populations will not be used for this study. Your child/guardian must have a current sports physical exam by a Medical Doctor in order to participate.

All researchers are National Athletic Trainers' Association certified athletic trainers. Dr. Iris F. Kimura will also be present at data collection sessions. Dr. Kimura is a University of Hawaii professor and state licensed physical therapist.

Procedures

Upon arrival at the test session your child/guardian will be assigned a number. They will then do a 5-minute warm-up. Next they will be divided into four groups. Participants in each group will do the assigned test. Once all groups have completed a single test, the groups will rotate. Once all rotations are complete, they will do the fitness test. After the fitness test, their participation in this study is complete. During the course of your child's/guardian's sport season, if they injure their knee, your Hanalani athletic trainer (Nicholas DePhillipo) will evaluate, treat, and record their knee injury for the study.

Your child/guardian will be participating in groups. It is imperative to be respectful of the other participant's test scores. All tests are individualized and their results may not be comparable to others in their group.

Risks and discomforts

Physical risk in this study is no greater than participating in sports. However, just as participation in sports, there is potential for experiencing physical harm from the test assessments. To minimize risks and discomforts before the testing, your child/guardian will do a 5-minute warm-up. This warm-up will be similar to what your child/guardian does before practice or games.

Potential benefits

There are no direct benefits for your child's/guardian's participation in this research study. General benefits are listed below:

- **Education.** Informational flyer about knee injury in sports will be given.
- **Assessment.** Evaluation by sports medicine professionals for risk factors that may influence knee injury.

Protection of confidentiality

All personal information will be kept confidential to the extent allowed by law. The UH Human Studies Program has authority to review these research records. The records will be kept in a locked file in the researcher's office. Digital files will be stored on a hard drive. This hard drive will be kept in the locked file. All personal information will be destroyed when the research project is completed. Your child's/guardian's identity will not be revealed in any publication of this study.

Voluntary participation

Your child's/guardian's participation in this research study is voluntary. They may choose not to participate. They may withdraw from the study at any time and will not be penalized in any way.

Contact information

If you have any questions or concerns, please contact Nicholas DePhillipo at 808.956.7421 or by email at ndephill@hawaii.edu. For questions about your rights as a research participant, contact the University of Hawaii Human Studies Program by phone at 808.956.5007 or by email at uhirb@hawaii.edu.

Consent:

I have read this consent form and have been given the opportunity to ask questions. I give my consent for my son/daughter/guardian to participate in this study.

Title: *The Knee Injury Screening Tool: Quantification of Neuromuscular Quality & Risk for Knee Injury in Adolescent Athletes*

Participant name: ____

Parent/guardian signature: ___________________________________ Date: _______________

APPENDIX D: Preparticipation Health Questionnaire

ID # ___________

Preparticipation Health Questionnaire

Please answer the following questions and provide explanation where needed:

*For our study, injury is defined as ANY injury diagnosed by a medical professional.
SEEK HELP FROM RESEARCHERS FOR CLARIFICATION IF UNAWARE

1) Previous history of lower leg injury? **Y / N**
    a. If so circle all that apply: foot /ankle lower leg knee hip
    b. Please explain all injuries including left or right side (i.e. Left ankle sprain):

    ____

    ____

    c. Circle number of previous injuries: 0 1 2 3 ≥4
2) History of lower leg surgery? **Y / N**
    a. If so please list surgical procedure, include body part and side (L/R)

    ____

3) Current symptoms—CHECK where applicable:

	Foot/Ankle	Lower leg	Knee	Hip
a. Pain	_______	_________	______	_____
b. Tingling/numbness	_______	_________	______	_____
c. Weakness	_______	_________	______	_____
d. Swelling	_______	_________	______	_____

Basic Demographic Information (circle only one):

1) Primary sport: Volleyball Basketball Soccer
2) History of athletic participation (years of experience): ________
3) Current level of sport participation: Intermediate JV Varsity

Participant Name (print) ____

Date of Birth _________________________ Gender_______ Grade _____________ Age _____

Height ___________________________ Weight __________________

Participant Signature ____ Date ________________

Parent/Guardian Signature ___________________________________Date __________________

APPENDIX E: IRB Assent Form

Assent Form for Participation in a Research Study
University of Hawaii at Manoa

Department of Kinesiology and Rehabilitation Science, University of Hawaii at Manoa
1337 Lower Campus Road, PE/A Complex Rm. 231, Honolulu, HI 96822
Phone: 808-956-7606

Title: *The Knee Injury Screening Tool: Quantification of Neuromuscular Quality & Risk for Knee Injury in Adolescent Athletes*

Description of the research and your participation

You have been invited to participate in a research study. This study will be conducted by Nicholas DePhillipo, ATC, CSCS, Joseph Smith, MS, ATC, Iris F. Kimura, PhD, ATC, PT, Timothy Cuddeback, ATC, CSCS, Adam Slabicki, ATC. The purpose of this study is to assess risk factors for knee injuries. Athletes in sports such as volleyball, basketball, and soccer are at risk for knee injury. Most injuries are not caused by contact with another player. They usually occur by changing direction, stopping suddenly, or landing from a jump.

The Knee Injury Screening Tool (KIST) is made up of five athletic tests. These tests will measure your balance, jumping, strength, and endurance. These qualities are important in playing sports safely. The tests are listed below.

1) Triple hop test
    a. You will stand on a single leg and hop three times forward as far as possible. The distance will be measured.
2) Single leg balance test
    a. You will stand on one leg and reach as far as possible in three directions while maintaining balance. The distance you can reach will be measured.
3) Abdominal strength
    a. You will lie on your back on a table. Then you will raise your legs together and slowly lower them towards the table. The angle of the legs will be recorded.
4) Jumping test
    a. You will step off a 1-foot box and jump as high as possible. You will be video taped. Your jump landing will be measured.
5) Fitness test
    a. You will run back and forth between 2 lines 20-meters apart. An audio recording will beep to keep you on pace. You will run until exhaustion or until you cannot maintain pace.

Study Population & Safety

You are being asked to volunteer to be in this study because you are a healthy student-athlete who plays volleyball, basketball, or soccer. Vulnerable populations will not be used for this study. You must have a current sports physical exam by a Medical Doctor in order to participate.

All researchers are National Athletic Trainers' Association certified athletic trainers. Dr. Iris F. Kimura will also be present at data collection sessions. Dr. Kimura is a University of Hawaii professor and state licensed physical therapist.

Procedures

Upon arrival at the test session you will be assigned a number. You will then do a 5-minute warm-up. Next you will be divided into four groups. Participants in each group will do the assigned test. Once all groups have completed a single test, the groups will rotate. Once all rotations are complete, you will do the fitness test. After the fitness test, the study is complete. During the course of your sport season, if you injure your knee it will be recorded. Your Hanalani athletic trainer (Nicholas DePhillipo) will evaluate, treat, and record your knee injury for the study.

You will be participating in groups. Please be respectful of the other participant's test scores. All tests are individualized and your results may not be comparable to others in your group.

Risks and discomforts

Physical risk in this study is no greater than participating in sports. However, just as participation in sports, there is potential for experiencing physical harm from the test assessments. To minimize risks and discomforts before the testing, you will do a 5-minute warm-up. The warm-up will be similar to what you do before practice or games.

Potential benefits

There are no direct benefits for participating in this research study. General benefits are listed below:

- **Education.** Informational flyer about knee injury in sports will be given.
- **Assessment.** Evaluation by sports medicine professionals for risk factors that may influence knee injury.

Protection of confidentiality

All personal information will be kept confidential to the extent allowed by law. The UH Human Studies Program has authority to review these research records. The records will be kept in a locked file in the researcher's office. Digital files will be stored on a hard drive. This hard drive will be kept in the locked file. All personal information will be destroyed when the research project is completed. Your identity will not be revealed in any publication of this study.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate. You may withdraw from the study at any time and will not be penalized in any way.

Contact information

If you have any questions or concerns, please contact Nicholas DePhillipo at 808.956.7421 or by email at ndephill@hawaii.edu. For questions about your rights as a research participant, contact the University of Hawaii Human Studies Program by phone at 808.956.5007 or by email at uhirb@hawaii.edu.

I, ____, fully understand that participating
Name of Participant
in this research study is my choice. I may choose to withdraw at any time during the study. If I begin to experience harm the test will be stopped. The cause of the harm will be evaluated and addressed.

I have read the previously stated procedures. I understand my role as a study participant. My effort will be assumed as maximal during athletic testing. I understand the risks and benefits of this study and understand that my participation is voluntary.

I have read this assent form and have been given the opportunity to ask questions.
I give my assent to participate in this study.

Title*: The Knee Injury Screening Tool: Quantification of Neuromuscular Quality & Risk for Knee Injury in Adolescent Athletes*

Participant name: ______________________________ Date: ____________

Participant signature: ___________________________ Date: ____________

APPENDIX F: Video Imaging Consent Form

VIDEO IMAGING CONSENT

Department of Kinesiology and Rehabilitation Science, University of Hawaii at Manoa
1337 Lower Campus Road, PE/A Complex Rm. 231, Honolulu, HI 96822
Phone: 808-956-7606

Title: *The Knee Injury Screening Tool: Quantification of Neuromuscular Quality & Risk for Knee Injury in Adolescent Athletes*

I understand that my son/daughter/guardian will be video recorded as part of this study. The movement of face, hands, legs, and body will be taped. The video image will be stored on a hard drive. This hard drive will be kept in a locked file cabinet. Video images will only be viewed by researchers directly involved with this study. No personal information will be stored on video. The image will be destroyed after the results of the study are published or 2 years after completion of the study, whichever is first.

I understand that if I do not agree to be video imaged, my son/daughter/guardian will not be able to take part in this study.

I give my consent for my son/daughter/guardian to be video imaged as part of this project.

______________________________	_________________________	_______________
Parent/Guardian Name (Print)	Signature	Date
______________________________	_________________________	_______________
Researcher’s Name (Print)	Signature	Date

APPENDIX G: Video Imaging Assent Form

VIDEO IMAGING ASSENT

Department of Kinesiology and Rehabilitation Science, University of Hawaii at Manoa
1337 Lower Campus Road, PE/A Complex Rm. 231, Honolulu, HI 96822
Phone: 808-956-7606

Title: *The Knee Injury Screening Tool: Quantification of Neuromuscular Quality & Risk for Knee Injury in Adolescent Athletes*

I understand that I will be video taped as part of this study. The movement of my face, hands, legs, and body will be taped. The video image will be stored on a hard drive. This hard drive will be kept in a locked file cabinet. Video images will only be viewed by researchers directly involved with this study. No personal information will be stored on video. The image will be destroyed after the results of the study are published or 2 years after completion of the study, whichever is first.

I understand that if I do not agree to be video imaged, I will not be able to take part in this study.

I give my consent to be video imaged as part of this project.

______________________	______________________	____________
Participant’s Name (Print)	Signature	Date
______________________	______________________	____________
Researcher’s Name (Print)	Signature	Date

APPENDIX H: Standardized Oral Instructions

Standardized Oral Instructions

Star Excursion Balance Test[42]

1. ‘‘Keep your stance foot flat on the floor with your hands on your hips.’’
2. ‘‘Make a reach with your other leg as far as possible and make a light tap on the measuring tape.’’
3. ‘‘Without pushing off the ground with your reaching leg, return it back to the center of the testing grid and place this foot on the ground next to the foot of the stance leg.’’
4. ‘‘You may make any movements you wish to reach as far as possible, as long as you keep your stance foot planted, your hands on your hips.’’
5. ‘‘If you tap more than once or slide the reaching foot during the reach, miss the tape measure with your tap, push off the floor with the reaching foot, lift your heel or your hands from the testing position, or are unable to return the reaching foot back to the starting position, we will repeat that trial.’’
6. “You will be allowed 4 practice trials in each direction and perform 3 successful reaches in all 3 directions for both legs.”

Triple Hop for Distance[27, 49]

1. “Stand with your big toe of your dominant leg on the starting line.”
2. “Perform 3 continuous maximal hops forward on your single leg, maintaining balance throughout the entire test.”
3. “After landing the 3rd hop, remain in the single-leg test position for a few seconds while I (the examiner) record your hop distance.”
4. “You may swing your arms and make any movements you wish to hop as far as possible. If you lose balance or contact the ground with the opposite leg, we will repeat the trial.”
5. You will be allowed 1 to 3 practice trials and perform a total of 3 trials on each leg with 30 seconds of rest in-between trials.”

Drop Jump Test[19]

1. “Start standing on both feet near the edge of the box.”
2. “Whenever you’re ready, step off the box, landing in front of it, and then perform a maximal vertical jump. You will be allowed 20 seconds to rest in between jumps.”

3. “You are allowed 1 practice trial. Then 3 test jump-lands will be recorded.”

Double-leg Lowering Test[67]

1. “Begin by laying on the treatment table face up, on your back. Grasp the sides of the table with both hands.”

2. “Next I (the tester) will raise both your legs to a vertical position, as you may feel a slight stretch in your hamstrings (rear leg muscles).”

3. “While keeping both your knees extended, tighten your abdominal muscles to hold your low back flat against the table and try to prevent your hips from rolling forward. (If having trouble “hiss” like a snake).”

4. “With your pelvis flat against the table, lower your legs at the same time as slowly as you can until the reach the table. Try to maintain the flat back posture throughout.”

5. “You will be allowed 1 practice trial then we will record 3 test trials. You are allowed to rest 20 seconds between each test trial.”

Multi-Stage Fitness Test[28]

1. “During this test, all of you will participate at the same time. You will begin by running back and forth between 2 lines 20 meters apart while running speed is controlled from CD audio ‘beeps’. Stand behind one of the lines facing the second line, and begin running when instructed by the audiotape. “

2. “You are required to run back and forth within the designated course and must touch the line at the same time the ‘beep’ is heard from the audiotape. Continue running between the two lines, turning when signaled by the recorded ‘beeps’. After about one minute, a sound indicates an increase in speed, and the ‘beeps’ will be closer together. This continues each minute with increasing running pace, demonstrated by running level (1-21).”

3. “If the line is not reached in time for each ‘beep’, you must run to the line, turn and try to catch up with the pace within 2 more ‘beeps’. If the line is reached before the beep sounds, you must wait at the line until the beep sounds for the stage. These stages will be announced through the audio tape and you should keep in mind what stage number you are in during and at the end of the test.”

4. “We (the researchers) will encourage you throughout the run and provide instruction in order for you to keep steady with the beat.”

5. “When you cannot keep up with the ‘beep’ or you become too exhausted to continue, remove yourself and report to the tester’s table so we can record your time and stage upon completion.”

6. “You will perform only 1 completion of this test today and its duration may range from 3 to 20 minutes.”

Appendix I: Raw Data

ID#	Gender	Grade	Grade_R	Sport_R	Level_R	Years_Experience	Height_(in)
1	0	11	3	2	3	11	64.25
2	0	12	3	1	3	10	67.5
3	0	11	3	2	3	7	66.25
4	0	12	3	2	3	4	68
5	0	10	2	2	3	1	67
6	0	12	3	2	3	5	59.64
7	0	9	2	2	3	4	65.25
8	0	11	3	2	3	4	63.5
9	0	9	2	1	1	1	63
11	0	9	2	1	1	2	63.6
12	0	12	3	1	3	4	62.5
13	0	10	2	3	3	10	65.4
14	0	9	2	1	1	2	63.75
15	0	10	2	1	3	3	64.8
16	0	10	2	1	3	5	62.75
17	0	9	2	1	3	1	67.75
18	0	10	2	1	3	4	64.8
19	0	9	2	1	1	2	64.8
20	0	9	2	1	3	6	60.25
21	0	10	2	1	3	2	69
22	0	11	3	2	3	6	66.5
23	0	11	3	2	3	7	62
25	1	12	3	2	3	11	66
26	1	12	3	2	3	6	68
27	1	11	3	2	3	7	68.5
28	1	12	3	2	3	6	73
29	1	11	3	2	3	4	65
30	1	11	3	2	3	11	66.5
31	1	9	2	2	2	3	64.5
32	1	12	3	2	3	7	71
33	1	12	3	2	3	6	69
34	1	12	3	2	3	2	75.5
35	1	11	3	2	2	7	67.5
36	1	11	3	2	3	9	64.8
37	1	11	3	2	2	6	68.25
38	1	10	2	2	2	10	68.5
39	1	12	3	2	3	4	66.75
40	1	10	2	2	2	10	71.5

ID#	Gender	Grade	Grade_R	Sport_R	Level_R	Years_Experience	Height_(in)
41	1	10	2	2	2	2	69.75
42	1	10	2	2	2	5	61.5
43	0	9	2	2	1	2	63.25
44	0	7	1	1	1	4	57.5
45	0	7	1	3	1	7	63.75
46	0	9	2	2	1	9	64.8
47	0	7	1	2	1	2	59
48	0	8	1	2	1	3	63.25
49	0	8	1	1	1	6	62
50	0	7	1	2	1	4	61.16
51	0	8	1	2	1	4	63.25
52	0	8	1	2	1	2	69.4
53	0	7	1	2	1	3	61
54	0	8	1	2	1	6	64.5
55	0	9	2	2	1	1	60.5
56	0	8	1	2	1	6	64.8
57	0	7	1	3	1	7	58
58	0	8	1	2	1	5	64.8
59	0	8	1	2	1	5	64.8
62	0	9	2	2	1	3	62.75
63	0	8	1	2	1	3	63.5
64	0	9	2	2	1	0	62.4
65	1	7	1	2	1	3	66.5
66	1	8	1	2	1	2	67
67	1	7	1	2	1	3	65.75
68	1	9	2	2	1	9	57
69	1	7	1	2	1	3	60.25
70	1	8	1	2	1	7	67
71	1	8	1	2	1	5	64.5
72	1	8	1	2	1	6	68.25
73	1	8	1	2	1	7	65
74	1	7	1	2	1	3	60
75	0	7	1	3	1	1	60.5
76	0	7	1	3	1	4	61.5
77	0	7	1	3	1	7	66
78	0	8	1	3	1	5	61.5
79	0	7	1	3	1	4.5	62.4
80	1	7	1	3	1	5	57.6

ID#	Gender	Grade	Grade_R	Sport_R	Level_R	Years_Experience	Height_(in)
81	1	8	1	2	1	6	62
82	1	9	2	2	1	4	63.25
83	0	9	2	3	1	4	62.75
84	1	10	2	2	2	9	62.5
85	1	10	2	2	2	2	69
86	1	10	2	2	2	4	64.75
87	0	9	2	3	2	10	64
88	0	9	2	3	2	6	63
89	0	10	2	3	2	10	63.25
90	0	10	2	3	2	7	61.22
91	0	10	2	3	2	3	64.8
92	0	9	2	3	2	9	67
93	0	12	3	3	3	7	61.81
94	0	12	3	2	3	8	65
96	1	10	2	3	3	5	65.25
97	1	9	2	3	3	12	67.91
98	1	9	2	3	3	5	66.25
99	1	10	2	3	2	3	69
100	0	12	3	3	3	4	66.75

ID#	Weight_(lbs)	Age(years)	Age_Rankings	BMI	Ht_(cm)	Wt_(kg)
1	116.5	16	2	19.84	163.20	52.95
2	136.8	17	2	21.11	171.45	62.18
3	124.5	16	2	19.94	168.28	56.59
4	152.7	17	2	23.22	172.72	69.41
5	185	15	2	28.97	170.18	84.09
6	98	17	2	19.37	151.49	44.55
7	146	14	1	24.11	165.74	66.36
8	140	16	2	24.41	161.29	63.64
9	97	13	1	17.18	160.02	44.09
11	201	14	1	34.93	161.54	91.36
12	108.6	16	2	19.54	158.75	49.36
13	135	16	2	22.19	166.12	61.36
14	187	15	2	32.35	161.93	85.00
15	119	14	1	19.92	164.59	54.09
16	121.5	15	2	21.69	159.39	55.23
17	123	14	1	18.84	172.09	55.91
18	117.6	15	2	19.69	164.59	53.45
19	125	14	1	20.93	164.59	56.82
20	111	14	1	21.50	153.04	50.45
21	171	15	2	25.25	175.26	77.73
22	121	16	2	19.24	168.91	55.00
23	98	16	2	17.92	157.48	44.55
25	154	17	2	24.85	167.64	70.00
26	191	17	2	29.04	172.72	86.82
27	136	16	2	20.38	173.99	61.82
28	157	17	2	20.71	185.42	71.36
29	162.5	15	2	27.04	165.10	73.86
30	127.5	16	2	20.27	168.91	57.95
31	117	14	1	19.77	163.83	53.18
32	160	17	2	22.31	180.34	72.73
33	150	17	2	22.15	175.26	68.18
34	190	17	2	23.43	191.77	86.36
35	135	16	2	20.83	171.45	61.36
36	127	16	2	21.26	164.59	57.73
37	163	16	2	24.60	173.36	74.09
38	212	16	2	31.76	173.99	96.36
39	159	17	2	25.09	169.55	72.27
40	181.5	15	2	24.96	181.61	82.50

ID#	Weight_(lbs)	Age(years)	Age_Rankings	BMI	Ht_(cm)	Wt_(kg)
41	162	15	2	23.41	177.17	73.64
42	84	15	2	15.61	156.21	38.18
43	176	14	1	30.93	160.66	80.00
44	78.8	12	1	16.76	146.05	35.82
45	98	12	1	16.95	161.93	44.55
46	134	14	1	22.43	164.59	60.91
47	100	12	1	20.20	149.86	45.45
48	100	13	1	17.57	160.66	45.45
49	96	13	1	17.56	157.48	43.64
50	90	12	1	16.91	155.35	40.91
51	112	13	1	19.68	160.66	50.91
52	206	13	1	30.07	176.28	93.64
53	115	13	1	21.73	154.94	52.27
54	115	13	1	19.43	163.83	52.27
55	79.2	14	1	15.21	153.67	36.00
56	103	12	1	17.24	164.59	46.82
57	86	12	1	17.97	147.32	39.09
58	142	14	1	23.77	164.59	64.55
59	104	13	1	17.41	164.59	47.27
62	116.1	15	2	20.73	159.39	52.77
63	129.5	14	1	22.58	161.29	58.86
64	120.7	14	1	21.79	158.50	54.86
65	123.8	12	1	19.68	168.91	56.27
66	119	13	1	18.64	170.18	54.09
67	129.5	13	1	21.06	167.01	58.86
68	73	14	1	15.80	144.78	33.18
69	73	13	1	14.14	153.04	33.18
70	166.5	13	1	26.07	170.18	75.68
71	152	13	1	25.68	163.83	69.09
72	147	13	1	22.19	173.36	66.82
73	179	13	1	29.78	165.10	81.36
74	83	12	1	16.21	152.40	37.73
75	98	12	1	18.82	153.67	44.55
76	96.5	12	1	17.94	156.21	43.86
77	130.5	12	1	21.06	167.64	59.32
78	91	12	1	16.91	156.21	41.36
79	85.5	12	1	15.44	158.50	38.86
80	95	12	1	20.13	146.30	43.18

ID#	Weight_(lbs)	Age(years)	Age_Rankings	BMI	Ht_(cm)	Wt_(kg)
81	102	13	1	18.65	157.48	46.36
82	127.75	14	1	22.45	160.66	58.07
83	108.8	14	1	19.42	159.39	49.45
84	111.5	15	2	20.07	158.75	50.68
85	146	16	2	21.56	175.26	66.36
86	114	16	2	19.12	164.47	51.82
87	152	14	1	26.09	162.56	69.09
88	102	13	1	18.07	160.02	46.36
89	129.3	15	2	22.72	160.66	58.77
90	120.59	15	2	22.62	155.50	54.81
91	125	15	2	20.93	164.59	56.82
92	165	14	1	25.84	170.18	75.00
93	103	17	2	18.95	157.00	46.82
94	129	17	2	21.46	165.10	58.64
96	138	15	2	22.79	165.74	62.73
97	137.58	15	2	20.97	172.49	62.54
98	144	14	1	23.06	168.28	65.45
99	129.6	16	2	19.14	175.26	58.91
100	138.8	17	2	21.90	169.55	63.09

ID#	LL_R	LL_L	DLLM_1	DLLM_2	DLLM_3	DLLM_Avg	DLLM_Adj100
1	88	88	50	50	60	36.67	40.33
2	91	90	60	60	55	31.67	34.83
3	90	90.5	65	60	65	26.67	29.33
4	96	96	85	85	85	5.00	5.50
5	93.5	92.5	65	75	75	18.33	20.17
6	76	76	50	45	43	44.00	48.40
7	89.5	90	65	62	62	27.00	29.70
8	82	82	65	80	80	15.00	16.50
9	90	90	55	70	70	25.00	27.50
11	83	83.5	60	60	60	30.00	33.00
12	89	89	65	65	65	25.00	27.50
13	90	90.5	65	60	65	26.67	29.33
14	86	85	60	60	65	28.33	31.17
15	85.5	85	55	65	60	30.00	33.00
16	83	83	55	55	60	33.33	36.67
17	97.5	97.5	60	60	60	30.00	33.00
18	89	89	70	70	70	20.00	22.00
19	89	89	55	60	65	30.00	33.00
20	79.5	80	80	75	75	13.33	14.67
21	94.5	93.5	75	75	75	15.00	16.50
22	94	94	75	80	70	15.00	16.50
23	89	89	65	60	60	28.33	31.17
25	87	87	70	75	80	15.00	16.50
26	92	92.5	85	70	65	16.67	18.33
27	93	93	65	60	70	25.00	27.50
28	98	98.5	65	60	65	26.67	29.33
29	85	84.5	50	60	60	33.33	36.67
30	92	92.5	55	55	55	35.00	38.50
31	88	88	75	65	75	18.33	20.17
32	91.5	92	65	65	65	25.00	27.50
33	92	93	50	60	60	33.33	36.67
34	103.5	103	60	70	60	26.67	29.33
35	88.5	89	55	55	65	31.67	34.83
36	84	85	45	50	50	41.67	45.83
37	89	89	85	75	70	13.33	14.67
38	89.5	89	60	65	60	28.33	31.17
39	88.5	88.5	65	60	65	26.67	29.33
40	96	95	65	65	75	21.67	23.83

ID#	LL_R	LL_L	DLLM_1	DLLM_2	DLLM_3	DLLM_Avg	DLLM_Adj100
41	96	95	75	70	80	15.00	16.50
42	85	85.5	40	40	40	50.00	55.00
43	85.5	86	55	60	60	31.67	34.83
44	75	75.5	65	55	60	30.00	33.00
45	87	86	60	60	60	30.00	33.00
46	87.5	88	65	55	65	28.33	31.17
47	85.5	85	60	60	55	31.67	34.83
48	85	86	60	60	50	33.33	36.67
49	85	85	45	60	55	36.67	40.33
50	80.5	80.5	55	55	60	33.33	36.67
51	85	84	45	45	50	43.33	47.67
52	92.5	91.5	75	70	70	18.33	20.17
53	81.5	81	65	60	60	28.33	31.17
54	88.5	89	55	70	65	26.67	29.33
55	83.5	84	55	55	55	35.00	38.50
56	90.5	91	35	30	30	58.33	64.17
57	82.5	83.5	55	45	35	45.00	49.50
58	86.5	86.5	65	70	80	18.33	20.17
59	86	86.5	35	30	40	55.00	60.50
62	88	88	55	55	55	35.00	38.50
63	88	88	65.5	65	70	23.17	25.48
64	87	86.5	45	50	50	41.67	45.83
65	90.5	90.5	60	60	60	30.00	33.00
66	94	94.5	60	60	60	30.00	33.00
67	86.5	86.5	60	55	50	35.00	38.50
68	78.5	79	60	50	65	31.67	34.83
69	87	86.5	60	60	65	28.33	31.17
70	89	89	75	70	80	15.00	16.50
71	85.5	86	70	70	70	20.00	22.00
72	96.5	97	50	60	70	30.00	33.00
73	91	89.5	80	80	85	8.33	9.17
74	84	84.5	60	60	65	28.33	31.17
75	82.5	82	60	50	55	35.00	38.50
76	84.5	83.5	45	40	45	46.67	51.33
77	90	90.5	60	65	60	28.33	31.17
78	86.5	87	65	60	70	25.00	27.50
79	84	84.5	55	55	45	38.33	42.17
80	77	76.5	60	60	60	30.00	33.00

ID#	LL_R	LL_L	DLLM_1	DLLM_2	DLLM_3	DLLM_Avg	DLLM_Adj100
81	83.5	83.5	50	40	50	43.33	47.67
82	84	83	60	60	60	30.00	33.00
83	84	83	65	70	60	25.00	27.50
84	84	84	85	80	80	8.33	9.17
85	99	99	80	65	75	16.67	18.33
86	85	84.5	70	65	70	21.67	23.83
87	86	86	70	70	65	21.67	23.83
88	87.5	88	50	50	55	38.33	42.17
89	84.5	84	60	50	60	33.33	36.67
90	80.5	80.5	65	65	70	23.33	25.67
91	87	86.5	55	50	50	38.33	42.17
92	91.5	91	80	55	80	18.33	20.17
93	84	84.5	45	50	60	38.33	42.17
94	84	84	40	35	40	51.67	56.83
96	91	91.5	75	65	70	20.00	22.00
97	94	94	60	60	55	31.67	34.83
98	90	90	45	40	60	41.67	45.83
99	89	89.5	60	60	60	30.00	33.00
100	87	86	75	60	60	25.00	27.50

ID#	DLLM_Avg_ Scaled	Overall_DLLM_ Scaled	Gender_DLLM_ Scaled	SEBT_Ant_MaxD_ Mean_Scaled
1	6.60	6.53	6.31	6.31
2	5.89	5.77	5.57	4.15
3	5.19	5.02	4.83	8.03
4	2.13	1.74	1.61	4.39
5	4.01	3.76	3.59	6.00
6	7.64	7.64	7.39	5.36
7	4.63	5.07	4.87	6.23
8	3.54	3.25	3.10	7.99
9	4.32	4.77	4.58	5.80
11	5.10	5.52	5.32	7.21
12	4.95	4.77	4.58	5.49
13	5.19	5.02	4.83	5.83
14	5.42	5.27	5.07	5.38
15	5.10	5.52	5.32	6.57
16	6.13	6.03	5.81	4.70
17	5.10	5.52	5.32	6.22
18	4.25	4.01	3.84	6.85
19	5.10	5.52	5.32	5.01
20	2.51	3.00	2.85	2.96
21	3.54	3.25	3.10	6.29
22	3.54	3.25	3.10	4.16
23	5.42	5.27	5.07	5.49
25	3.62	3.25	3.46	5.41
26	3.88	3.51	3.73	4.65
27	5.20	4.77	5.07	5.24
28	5.47	5.02	5.33	3.83
29	6.52	6.03	6.40	3.60
30	6.79	6.28	6.67	3.65
31	3.78	3.76	4.00	3.69
32	5.20	4.77	5.07	6.45
33	6.52	6.03	6.40	4.66
34	5.47	5.02	5.33	6.49
35	6.26	5.77	6.14	4.98
36	7.84	7.29	7.74	4.13
37	3.35	3.00	3.19	6.52
38	5.73	5.27	5.60	3.56
39	5.47	5.02	5.33	5.14
40	4.67	4.26	4.53	5.09

ID#	DLLM_Avg_ Scaled	Overall_DLLM_ Scaled	Gender_DLLM_ Scaled	SEBT_Ant_MaxD_ Mean_Scaled
41	3.62	3.25	3.46	4.63
42	9.16	8.55	9.08	5.40
43	5.35	5.77	5.57	5.23
44	5.10	5.52	5.32	7.67
45	5.10	5.52	5.32	1.75
46	4.84	5.27	5.07	4.00
47	5.35	5.77	5.57	4.66
48	5.61	6.03	5.81	6.26
49	6.13	6.53	6.31	5.03
50	5.61	6.03	5.81	6.02
51	7.16	7.54	7.30	4.79
52	3.29	3.76	3.59	6.32
53	4.84	5.27	5.07	5.71
54	4.58	5.02	4.83	5.12
55	5.87	6.28	6.06	4.39
56	9.49	9.81	9.52	6.76
57	7.42	7.79	7.54	5.11
58	3.29	3.76	3.59	7.57
59	8.97	9.30	9.02	5.06
62	6.36	6.28	6.06	3.80
63	4.04	4.49	4.31	4.53
64	6.91	7.29	7.05	5.96
65	5.65	5.52	5.87	6.02
66	5.65	5.52	5.87	3.34
67	6.46	6.28	6.67	7.32
68	5.92	5.77	6.14	7.40
69	5.39	5.27	5.60	6.19
70	3.24	3.25	3.46	3.56
71	4.05	4.01	4.26	5.90
72	5.65	5.52	5.87	5.52
73	2.17	2.25	2.39	4.66
74	5.39	5.27	5.60	8.16
75	5.87	6.28	6.06	3.71
76	7.68	8.04	7.79	4.19
77	4.84	5.27	5.07	6.06
78	4.32	4.77	4.58	4.07
79	6.39	6.78	6.55	4.14
80	5.65	5.52	5.87	6.60

ID#	DLLM_Avg_ Scaled	Overall_DLLM_ Scaled	Gender_DLLM_ Scaled	SEBT_Ant_MaxD_ Mean_Scaled
81	7.80	7.54	8.01	4.74
82	5.65	5.52	5.87	3.51
83	4.32	4.77	4.58	8.29
84	2.56	2.25	2.39	7.19
85	3.88	3.51	3.73	4.34
86	4.67	4.26	4.53	7.75
87	3.80	4.26	4.08	3.29
88	6.39	6.78	6.55	6.27
89	6.13	6.03	5.81	3.05
90	4.72	4.51	4.33	3.73
91	6.84	6.78	6.55	4.66
92	3.29	3.76	3.59	4.27
93	6.84	6.78	6.55	5.15
94	8.72	8.80	8.53	6.05
96	4.41	4.01	4.26	6.61
97	6.26	5.77	6.14	5.66
98	7.53	7.29	7.74	5.80
99	5.99	5.52	5.87	5.38
100	4.95	4.77	4.58	4.87

ID#	SEBT_Ant_MaxD_ Sum_Scaled	Absolute_Anterior_ Average	SEBT_ R_Ant1	SEBT_ R_Ant2	SEBT_ R_Ant3
1	12.62	69.00	66.04	73.66	71.12
2	8.30	60.96	55.88	58.42	63.50
3	16.07	74.08	68.58	71.12	73.66
4	8.78	67.31	68.58	66.04	68.58
5	12.01	71.12	66.04	76.20	71.12
6	10.72	55.88	50.80	48.26	55.88
7	12.46	69.85	68.58	71.12	73.66
8	15.98	72.39	73.66	73.66	73.66
9	11.59	67.31	58.42	68.58	63.50
11	14.42	66.04	58.42	58.42	66.04
12	10.98	65.62	66.04	68.58	68.58
13	11.65	68.16	63.50	66.04	71.12
14	10.76	60.96	60.96	68.58	60.96
15	13.15	67.73	60.96	63.50	66.04
16	9.39	56.73	50.80	55.88	58.42
17	12.43	75.78	68.58	76.20	78.74
18	13.69	70.70	63.50	71.12	73.66
19	10.02	63.92	60.96	68.58	68.58
20	5.91	49.53	53.34	50.80	53.34
21	12.58	71.54	71.12	68.58	76.20
22	8.32	64.35	66.04	60.96	66.04
23	10.98	65.62	55.88	66.04	68.58
25	10.82	64.35	63.50	66.04	63.50
26	9.30	59.27	55.88	53.34	68.58
27	10.47	68.16	66.04	68.58	66.04
28	7.67	66.04	63.50	66.04	71.12
29	7.21	56.73	55.88	58.42	60.96
30	7.29	61.81	60.96	63.50	63.50
31	7.39	59.69	60.96	60.96	63.50
32	12.89	72.81	76.20	76.20	73.66
33	9.32	65.19	66.04	66.04	66.04
34	12.97	79.59	73.66	78.74	78.74
35	9.96	64.77	66.04	68.58	68.58
36	8.27	57.57	55.88	53.34	58.42
37	13.04	69.00	66.04	66.04	66.04
38	7.12	59.27	55.88	58.42	58.42
39	10.29	64.77	58.42	63.50	63.50
40	10.18	68.16	66.04	60.96	68.58

ID#	SEBT_Ant_MaxD_ Sum_Scaled	Absolute_Anterior_ Average	SEBT_ R_Ant1	SEBT_ R_Ant2	SEBT_ R_Ant3
41	9.27	67.31	66.04	68.58	73.66
42	10.80	63.50	63.50	63.50	66.04
43	10.45	61.81	58.42	60.96	66.04
44	15.34	63.08	60.96	63.50	68.58
45	3.50	49.53	53.34	53.34	53.34
46	8.00	60.11	58.42	60.96	60.96
47	9.32	59.69	55.88	58.42	60.96
48	12.53	67.73	63.50	66.04	66.04
49	10.06	61.38	60.96	63.50	60.96
50	12.05	62.23	58.42	55.88	60.96
51	9.58	60.96	58.42	60.96	60.96
52	12.64	72.39	68.58	71.12	73.66
53	11.42	60.96	55.88	58.42	63.50
54	10.25	62.23	71.12	58.42	66.04
55	8.79	57.15	53.34	55.88	60.96
56	13.52	73.24	68.58	73.66	71.12
57	10.22	58.00	63.50	55.88	60.96
58	15.13	69.85	60.96	66.04	66.04
59	10.12	61.81	53.34	60.96	63.50
62	7.60	59.27	55.88	53.34	55.88
63	9.06	60.96	58.42	60.96	63.50
64	11.93	64.35	53.34	60.96	63.50
65	12.04	68.58	66.04	71.12	73.66
66	6.68	62.23	55.88	60.96	60.96
67	14.64	70.70	73.66	71.12	71.12
68	14.80	64.35	66.04	60.96	63.50
69	12.38	67.31	66.04	63.50	68.58
70	7.11	57.15	53.34	55.88	60.96
71	11.81	64.35	66.04	68.58	73.66
72	11.05	71.54	68.58	71.12	68.58
73	9.33	63.50	60.96	66.04	68.58
74	16.33	68.16	78.74	71.12	66.04
75	7.42	54.19	55.88	53.34	53.34
76	8.39	58.00	53.34	53.34	55.88
77	12.13	69.85	68.58	68.58	71.12
78	8.15	58.42	58.42	55.88	58.42
79	8.29	58.42	53.34	55.88	55.88
80	13.20	57.57	55.88	58.42	66.04

ID#	SEBT_Ant_MaxD_Sum_Scaled	Absolute_Anterior_Average	SEBT_R_Ant1	SEBT_R_Ant2	SEBT_R_Ant3
81	9.49	59.69	58.42	58.42	58.42
82	7.02	56.73	58.42	58.42	58.42
83	16.58	70.70	60.96	71.12	76.20
84	14.37	65.19	63.50	66.04	71.12
85	8.68	69.00	68.58	71.12	73.66
86	15.49	69.43	68.58	68.58	73.66
87	6.58	55.03	50.80	53.34	53.34
88	12.53	71.12	71.12	71.12	71.12
89	6.11	53.76	53.34	53.34	53.34
90	7.46	53.34	53.34	55.88	55.88
91	9.31	61.38	58.42	58.42	60.96
92	8.53	63.50	60.96	63.50	63.50
93	10.31	61.38	60.96	63.50	63.50
94	12.10	65.19	60.96	63.50	66.04
96	13.23	71.54	71.12	73.66	73.66
97	11.31	69.43	66.04	71.12	73.66
98	11.61	68.16	68.58	68.58	71.12
99	10.76	66.46	63.50	63.50	60.96
100	9.75	62.23	63.50	66.04	63.50

ID#	Average_Absolute_Ant_R	SEBT_Ant_R_MaxD	SEBT_Ant_R_MaxD_Scaled	SEBT_R_Post1	SEBT_R_Post2	SEBT_R_Post3
1	70.27	83.70	7.21	48.26	53.34	58.42
2	59.27	70.56	4.26	81.28	86.36	86.36
3	71.12	81.39	6.69	76.20	83.82	93.98
4	67.73	71.44	4.46	78.74	81.28	83.82
5	71.12	82.38	6.91	76.20	78.74	83.82
6	51.65	73.53	4.93	53.34	60.96	68.58
7	71.12	81.84	6.79	71.12	71.12	76.20
8	73.66	89.83	8.58	68.58	71.12	68.58
9	63.50	76.20	5.53	78.74	76.20	83.82
11	60.96	79.09	6.18	73.66	76.20	81.28
12	67.73	77.06	5.72	66.04	68.58	68.58
13	66.89	78.59	6.06	63.50	71.12	73.66
14	63.50	80.68	6.53	58.42	58.42	68.58
15	63.50	77.69	5.86	58.42	63.50	63.50
16	55.03	70.39	4.23	60.96	66.04	73.66
17	74.51	80.76	6.55	78.74	78.74	76.20
18	69.43	82.76	7.00	71.12	78.74	86.36
19	66.04	77.06	5.72	55.88	58.42	55.88
20	52.49	66.68	3.39	60.96	73.66	76.20
21	71.97	81.50	6.72	68.58	68.58	73.66
22	64.35	70.26	4.20	78.74	81.28	81.28
23	63.50	77.06	5.72	76.20	76.20	78.74
25	64.35	75.91	5.27	86.36	83.82	86.36
26	59.27	74.14	4.86	78.74	83.82	83.82
27	66.89	73.74	4.77	93.98	99.06	99.06
28	66.89	72.20	4.42	91.44	93.98	93.98
29	58.42	72.14	4.40	76.20	88.90	81.28
30	62.65	68.65	3.60	81.28	88.90	91.44
31	61.81	72.16	4.41	81.28	78.74	73.66
32	75.35	82.83	6.85	88.90	96.52	99.06
33	66.04	71.01	4.14	83.82	93.98	93.98
34	77.05	76.45	5.39	83.82	88.90	93.98
35	67.73	77.06	5.53	83.82	93.98	88.90
36	55.88	68.73	3.62	81.28	88.90	93.98
37	66.04	74.20	4.87	63.50	63.50	63.50
38	57.57	65.64	2.91	83.82	91.44	96.52
39	61.81	71.75	4.31	86.36	83.82	83.82
40	65.19	72.19	4.41	83.82	76.20	83.82

ID#	Average_ Absolute_Ant_R	SEBT_Ant_ R_MaxD	SEBT_Ant_R_ MaxD_Scaled	SEBT_ R_Post1	SEBT_ R_Post2	SEBT_ R_Post3
41	69.43	77.54	5.64	86.36	83.82	96.52
42	64.35	77.24	5.57	68.58	73.66	76.20
43	61.81	76.79	5.66	60.96	60.96	55.88
44	64.35	90.83	8.81	66.04	60.96	63.50
45	53.34	62.02	2.35	55.88	58.42	58.42
46	60.11	69.27	3.98	71.12	63.50	68.58
47	58.42	71.72	4.52	55.88	60.96	60.96
48	65.19	76.79	5.66	68.58	71.12	76.20
49	61.81	74.71	5.19	55.88	66.04	58.42
50	58.42	75.73	5.42	60.96	66.04	68.58
51	60.11	72.57	4.72	71.12	73.66	78.74
52	71.12	80.50	6.49	73.66	73.66	76.20
53	59.27	78.40	6.02	68.58	66.04	73.66
54	65.19	79.91	6.36	60.96	68.58	76.20
55	56.73	72.57	4.72	58.42	55.88	58.42
56	71.12	80.95	6.59	68.58	71.12	76.20
57	60.11	76.05	5.49	63.50	68.58	71.12
58	64.35	76.35	5.56	71.12	78.74	81.28
59	59.27	73.41	4.90	53.34	55.88	48.26
62	55.03	63.50	2.68	58.42	50.80	66.04
63	60.96	72.16	4.62	71.12	63.50	73.66
64	59.27	73.41	4.90	73.66	68.58	68.58
65	70.27	81.39	6.52	73.66	73.66	76.20
66	59.27	64.51	2.65	76.20	68.58	76.20
67	71.97	85.16	7.39	81.28	83.82	83.82
68	63.50	83.59	7.03	68.58	66.04	81.28
69	66.04	79.28	6.04	68.58	76.20	73.66
70	56.73	68.49	3.56	78.74	78.74	78.74
71	69.43	85.65	7.50	73.66	76.20	76.20
72	69.43	73.32	4.67	88.90	88.90	88.90
73	65.19	76.63	5.43	68.58	73.66	73.66
74	71.97	93.18	9.23	81.28	78.74	88.90
75	54.19	68.15	3.72	45.72	53.34	55.88
76	54.19	66.92	3.45	60.96	76.20	78.74
77	69.43	78.59	6.06	81.28	86.36	91.44
78	57.57	67.15	3.50	73.66	81.28	81.28
79	55.03	66.13	3.27	63.50	63.50	68.58
80	60.11	86.33	7.66	58.42	63.50	60.96

ID#	Average_Absolute_Ant_R	SEBT_Ant_R_MaxD	SEBT_Ant_R_MaxD_Scaled	SEBT_R_Post1	SEBT_R_Post2	SEBT_R_Post3
81	58.42	69.96	3.90	58.42	63.50	66.04
82	58.42	70.39	4.00	83.82	86.36	93.98
83	69.43	91.81	9.03	73.66	76.20	76.20
84	66.89	84.67	7.27	71.12	71.12	81.28
85	71.12	74.40	4.92	83.82	83.82	83.82
86	70.27	87.17	7.85	73.66	76.20	81.28
87	52.49	62.02	2.35	71.12	78.74	76.20
88	71.12	80.82	6.56	73.66	76.20	81.28
89	53.34	63.50	2.68	76.20	76.20	78.74
90	55.03	69.42	4.01	66.04	66.04	66.04
91	59.27	70.47	4.25	66.04	68.58	71.12
92	62.65	69.78	4.09	60.96	68.58	63.50
93	62.65	75.15	5.29	71.12	68.58	68.58
94	63.50	78.62	6.07	63.50	63.50	66.04
96	72.81	80.50	6.32	78.74	78.74	81.28
97	70.27	78.36	5.83	91.44	91.44	96.52
98	69.43	79.02	5.98	81.28	76.20	81.28
99	62.65	70.95	4.13	76.20	73.66	76.20
100	64.35	76.79	5.66	71.12	73.66	71.12

ID#	SEBT_Post_ R_MaxD%	Ant_MaxD_ Mean_R_L	Post_MaxD_ Mean_R_L	Med_MaxD_ Mean_R_L	SEBT_ R_Med1	SEBT_ R_Med2
1	66.39	80.82	69.27	89.48	76.20	76.20
2	95.96	70.17	94.03	102.44	86.36	86.36
3	103.85	91.50	102.72	111.17	86.36	93.98
4	87.31	71.44	89.96	95.25	88.90	91.44
5	90.62	79.22	84.70	105.20	93.98	96.52
6	90.24	76.87	86.89	88.57	53.34	63.50
7	84.67	80.65	86.32	99.07	78.74	81.28
8	86.73	89.83	85.18	96.02	60.96	71.12
9	93.13	79.02	90.31	95.96	78.74	83.82
11	97.34	86.98	99.16	105.27	78.74	86.36
12	77.06	77.06	79.91	94.18	73.66	73.66
13	81.39	78.80	84.44	94.29	73.66	83.82
14	80.68	75.78	77.26	83.17	68.58	63.50
15	74.71	83.41	75.97	95.34	71.12	73.66
16	88.75	73.45	87.22	91.81	66.04	66.04
17	80.76	80.76	82.06	100.30	86.36	86.36
18	97.03	84.19	95.61	104.17	73.66	81.28
19	65.64	74.20	68.49	88.47	78.74	78.74
20	95.25	63.69	90.76	95.54	71.12	78.74
21	78.78	81.07	82.40	105.39	93.98	96.52
22	86.47	70.26	82.41	87.82	73.66	83.82
23	88.47	77.06	87.04	88.47	66.04	76.20
25	99.26	75.91	102.18	113.86	91.44	91.44
26	90.62	72.96	89.48	90.86	83.82	83.82
27	106.52	75.11	103.78	117.44	86.36	106.68
28	95.41	69.80	95.65	102.12	96.52	99.06
29	105.21	68.94	97.43	106.40	81.28	83.82
30	98.85	68.84	96.36	103.26	88.90	88.90
31	92.36	69.27	93.81	102.47	81.28	83.82
32	107.67	80.28	109.36	110.74	96.52	99.06
33	101.05	72.78	96.08	101.57	93.98	96.52
34	91.24	79.94	88.57	97.17	91.44	93.98
35	105.60	74.40	107.33	113.06	83.82	91.44
36	110.56	70.65	108.20	106.70	76.20	78.74
37	71.35	79.91	75.63	102.74	76.20	71.12
38	108.45	68.30	108.15	108.14	81.28	91.44
39	97.58	74.62	97.58	101.89	83.82	88.90
40	88.23	74.46	89.09	107.69	93.98	93.98

ID#	SEBT_Post_ R_MaxD%	Ant_MaxD_ Mean_R_L	Post_MaxD_ Mean_R_L	Med_MaxD_ Mean_R_L	SEBT_ R_Med1	SEBT_ R_Med2
41	101.60	73.16	94.46	93.11	91.44	88.90
42	89.12	75.97	89.38	92.36	71.12	78.74
43	70.88	75.53	72.58	88.86	71.12	73.66
44	87.47	87.75	89.46	106.32	76.20	81.28
45	67.93	57.29	73.38	76.37	66.04	68.58
46	80.82	69.47	83.95	88.28	76.20	73.66
47	71.72	72.99	71.51	89.38	71.12	73.66
48	88.60	81.72	89.13	99.57	76.20	73.66
49	77.69	74.71	76.20	88.15	76.20	73.66
50	85.19	80.46	86.77	96.24	73.66	73.66
51	93.74	73.64	91.69	99.18	76.20	81.28
52	83.28	81.44	82.83	99.41	76.20	86.36
53	90.94	78.15	87.54	98.48	73.66	78.74
54	85.62	74.40	82.99	100.17	83.82	83.82
55	69.55	71.27	71.28	83.41	68.58	63.50
56	83.74	83.98	83.97	88.18	73.66	76.20
57	85.17	74.97	82.61	99.43	86.36	73.66
58	93.97	89.56	95.43	99.84	81.28	83.82
59	64.60	75.10	67.74	89.83	76.20	71.12
62	75.05	69.27	73.60	88.03	76.20	76.20
63	83.70	72.16	82.26	93.81	66.04	76.20
64	85.16	80.50	89.29	102.46	76.20	78.74
65	84.20	78.59	87.01	96.83	83.82	86.36
66	80.63	67.38	79.50	92.97	81.28	86.36
67	96.90	83.69	95.43	91.03	76.20	76.20
68	102.89	83.86	98.36	104.82	78.74	81.28
69	88.09	79.06	89.30	92.23	71.12	76.20
70	88.47	68.49	87.04	92.75	81.28	83.82
71	88.60	78.47	87.38	103.67	81.28	88.90
72	91.65	76.14	89.25	94.51	86.36	83.82
73	82.30	73.20	78.83	90.02	73.66	76.20
74	105.21	87.41	96.45	111.54	88.90	86.36
75	68.15	67.94	71.02	84.92	66.04	68.58
76	94.30	71.04	90.74	95.26	81.28	81.28
77	101.04	80.22	106.96	108.38	83.82	88.90
78	93.43	70.28	93.70	92.26	71.12	68.58
79	81.16	70.86	79.89	102.50	81.28	78.74
80	83.01	81.10	79.44	97.66	73.66	76.20

ID#	SEBT_Post_R_MaxD%	Ant_MaxD_Mean_R_L	Post_MaxD_Mean_R_L	Med_MaxD_Mean_R_L	SEBT_R_Med1	SEBT_R_Med2
81	79.09	73.01	82.13	91.26	68.58	71.12
82	113.23	68.45	100.46	104.98	86.36	86.36
83	91.81	91.26	89.75	98.87	76.20	81.28
84	96.76	83.15	95.25	105.83	73.66	73.66
85	84.67	71.84	84.67	91.08	81.28	88.90
86	96.19	85.42	95.91	100.40	78.74	71.12
87	91.56	66.45	88.60	97.47	81.28	83.82
88	92.36	81.05	88.27	92.64	76.20	78.74
89	93.74	64.82	88.95	87.42	71.12	71.12
90	82.04	67.84	83.61	88.35	71.12	71.12
91	82.22	73.19	81.98	89.31	76.20	78.74
92	75.36	70.98	77.93	84.90	68.58	71.12
93	84.17	75.37	87.44	93.46	73.66	78.74
94	78.62	80.13	80.13	90.71	76.20	76.20
96	88.83	80.72	91.87	94.64	83.82	86.36
97	102.68	77.01	99.98	104.03	91.44	91.44
98	90.31	77.61	90.31	95.96	83.82	86.36
99	85.14	75.43	82.52	96.77	73.66	81.28
100	85.65	73.43	82.24	89.57	78.74	78.74

ID#	SEBT_ R_Med3	SEBT_Med_ R_MaxD%	Ant_MaxD_ R_L_difference	SEBT_ L_Ant1	SEBT_ L_Ant2	SEBT_ L_Ant3	SEBT_Ant_ L_MaxD%
1	81.28	92.36	5.77	66.04	68.58	68.58	77.93
2	91.44	101.60	0.78	63.50	60.96	63.50	69.78
3	99.06	109.46	20.21	91.44	71.12	68.58	101.60
4	93.98	97.90	0.00	63.50	68.58	68.58	71.44
5	106.68	115.33	6.31	71.12	71.12	71.12	76.06
6	71.12	93.58	6.68	60.96	60.96	58.42	80.21
7	83.82	93.13	2.38	66.04	68.58	71.12	79.46
8	76.20	92.93	0.00	68.58	71.12	73.66	89.83
9	86.36	95.96	5.64	68.58	71.12	73.66	81.84
11	81.28	103.43	15.78	63.50	71.12	78.74	94.87
12	78.74	88.47	0.00	68.58	58.42	63.50	77.06
13	83.82	92.62	0.44	68.58	68.58	71.12	79.02
14	63.50	80.68	9.80	55.88	58.42	60.96	70.88
15	78.74	92.64	11.43	66.04	73.66	76.20	89.12
16	73.66	88.75	6.12	50.80	63.50	60.96	76.51
17	93.98	96.39	0.00	76.20	76.20	78.74	80.76
18	88.90	99.89	2.85	66.04	76.20	73.66	85.62
19	78.74	88.47	5.71	60.96	63.50	60.96	71.35
20	71.12	98.43	5.97	45.72	48.26	45.72	60.70
21	99.06	105.95	0.86	66.04	71.12	76.20	80.63
22	83.82	89.17	0.00	63.50	63.50	66.04	70.26
23	81.28	91.33	0.00	66.04	68.58	68.58	77.06
25	99.06	113.86	0.00	66.04	63.50	63.50	75.91
26	83.82	90.62	2.36	66.04	55.88	55.88	71.78
27	109.22	117.44	2.73	66.04	71.12	71.12	76.47
28	99.06	100.57	4.82	63.50	66.04	66.04	67.39
29	91.44	108.21	6.40	53.34	55.88	55.88	65.74
30	93.98	101.60	0.37	58.42	60.96	63.50	69.02
31	91.44	103.91	5.77	58.42	55.88	58.42	66.39
32	101.60	110.43	5.10	68.58	71.12	71.12	77.73
33	99.06	106.52	3.53	63.50	68.58	60.96	74.54
34	99.06	96.17	6.99	81.28	78.74	86.36	83.44
35	96.52	108.45	5.30	60.96	63.50	60.96	71.75
36	91.44	107.58	3.84	60.96	60.96	55.88	72.57
37	78.74	88.47	11.42	68.58	71.12	76.20	85.62
38	93.98	105.60	5.31	63.50	58.42	60.96	70.95
39	88.90	100.45	5.74	68.58	68.58	66.04	77.49
40	96.52	101.60	4.54	66.04	73.66	73.66	76.73

ID#	SEBT_ R_Med3	SEBT_Med_ R_MaxD%	Ant_MaxD_R_ L_difference	SEBT_ L_Ant1	SEBT_ L_Ant2	SEBT_ L_Ant3	SEBT_Ant_ L_MaxD%
41	91.44	96.25	8.75	63.50	66.04	66.04	68.79
42	78.74	92.09	2.53	63.50	60.96	63.50	74.71
43	76.20	88.60	2.52	58.42	63.50	63.50	74.27
44	76.20	107.66	6.17	60.96	60.96	63.50	84.67
45	68.58	79.74	9.47	45.72	45.72	45.72	52.55
46	78.74	89.48	0.40	58.42	60.96	60.96	69.67
47	76.20	89.65	2.55	58.42	60.96	63.50	74.27
48	78.74	91.56	9.87	66.04	73.66	71.12	86.66
49	76.20	89.65	0.00	63.50	60.96	58.42	74.71
50	71.12	91.50	9.47	63.50	66.04	68.58	85.19
51	78.74	96.76	2.13	60.96	63.50	60.96	74.71
52	93.98	102.71	1.88	71.12	73.66	76.20	82.38
53	81.28	100.35	0.48	63.50	60.96	63.50	77.91
54	88.90	99.89	11.03	58.42	60.96	58.42	68.88
55	68.58	81.64	2.61	58.42	58.42	55.88	69.96
56	73.66	83.74	6.06	68.58	78.74	78.74	87.01
57	73.66	103.43	2.16	60.96	50.80	55.88	73.89
58	88.90	102.77	26.43	88.90	66.04	71.12	102.77
59	71.12	88.09	3.38	60.96	66.04	66.04	76.79
62	76.20	86.59	11.55	58.42	66.04	66.04	75.05
63	83.82	95.25	0.00	63.50	58.42	60.96	72.16
64	83.82	96.90	14.18	66.04	76.20	66.04	87.59
65	88.90	98.23	5.61	66.04	66.04	68.58	75.78
66	88.90	94.07	5.75	63.50	66.04	66.04	70.26
67	81.28	93.97	2.94	68.58	68.58	71.12	82.22
68	83.82	106.10	0.53	66.04	66.04	63.50	84.13
69	78.74	91.03	0.46	68.58	68.58	68.58	78.83
70	83.82	94.18	0.00	53.34	60.96	58.42	68.49
71	83.82	103.37	14.35	60.96	58.42	58.42	71.30
72	91.44	94.27	5.64	71.12	76.20	73.66	78.96
73	73.66	85.14	6.85	58.42	63.50	63.50	69.78
74	96.52	114.22	11.54	68.58	60.96	63.50	81.64
75	68.58	83.63	0.41	55.88	53.34	53.34	67.73
76	81.28	97.34	8.23	60.96	63.50	60.96	75.15
77	88.90	98.23	3.26	68.58	73.66	68.58	81.84
78	71.12	81.75	6.26	58.42	63.50	55.88	73.41
79	88.90	105.21	9.47	60.96	63.50	60.96	75.60
80	81.28	106.25	10.46	58.42	50.80	55.88	75.87

ID#	SEBT_R_Med3	SEBT_Med_R_MaxD%	Ant_MaxD_R_L_difference	SEBT_L_Ant1	SEBT_L_Ant2	SEBT_L_Ant3	SEBT_Ant_L_MaxD%
81	76.20	91.26	6.08	60.96	58.42	63.50	76.05
82	91.44	110.17	3.86	55.88	53.34	55.88	66.52
83	83.82	100.99	1.09	68.58	76.20	71.12	90.71
84	83.82	99.79	3.02	58.42	63.50	68.58	81.64
85	81.28	89.80	5.13	68.58	66.04	66.04	69.27
86	83.82	99.20	3.50	71.12	68.58	66.04	83.67
87	81.28	97.47	8.86	55.88	55.88	60.96	70.88
88	78.74	89.48	0.46	71.12	71.12	71.12	81.28
89	68.58	84.67	2.63	53.34	53.34	55.88	66.13
90	73.66	91.50	3.16	50.80	50.80	53.34	66.26
91	76.20	91.03	5.43	60.96	63.50	66.04	75.91
92	76.20	83.74	2.39	63.50	63.50	66.04	72.17
93	78.74	93.18	0.45	58.42	63.50	58.42	75.60
94	78.74	93.74	3.02	66.04	66.04	68.58	81.64
96	83.82	94.38	0.44	66.04	71.12	73.66	80.95
97	93.98	99.98	2.70	71.12	66.04	68.58	75.66
98	88.90	98.78	2.82	66.04	68.58	66.04	76.20
99	83.82	93.65	8.96	68.58	71.12	71.12	79.91
100	78.74	91.56	6.72	58.42	60.96	60.96	70.07

ID#	SEBT_Average_ Ant_L_Absolute	SEBT_Ant_ L_MaxD_Scaled	SEBT_ L_Post1	SEBT_ L_Post2	SEBT_ L_Post3	SEBT_Post_ L_MaxD%
1	67.73	5.41	63.50	60.96	58.42	72.16
2	62.65	4.04	83.82	81.28	81.28	92.11
3	77.05	9.37	81.28	86.36	91.44	101.60
4	66.89	4.32	78.74	86.36	88.90	92.60
5	71.12	5.09	66.04	71.12	73.66	78.78
6	60.11	5.79	63.50	60.96	63.50	83.55
7	68.58	5.66	66.04	78.74	76.20	87.98
8	71.12	7.40	60.96	66.04	68.58	83.63
9	71.12	6.06	71.12	73.66	78.74	87.49
11	71.12	8.24	63.50	78.74	83.82	100.99
12	63.50	5.26	68.58	73.66	73.66	82.76
13	69.43	5.59	66.04	73.66	78.74	87.49
14	58.42	4.22	58.42	63.50	63.50	73.84
15	71.97	7.28	58.42	63.50	66.04	77.24
16	58.42	5.17	66.04	66.04	71.12	85.69
17	77.05	5.88	71.12	81.28	81.28	83.36
18	71.97	6.69	71.12	76.20	83.82	94.18
19	61.81	4.30	63.50	63.50	63.50	71.35
20	46.57	2.52	55.88	60.96	68.58	86.26
21	71.12	5.86	73.66	73.66	81.28	86.01
22	64.35	4.12	63.50	66.04	73.66	78.36
23	67.73	5.26	71.12	73.66	76.20	85.62
25	64.35	5.55	86.36	86.36	91.44	105.10
26	59.27	4.44	76.20	81.28	81.28	88.35
27	69.43	5.70	86.36	88.90	93.98	101.05
28	65.19	3.25	93.98	91.44	86.36	95.90
29	55.03	2.81	76.20	76.20	76.20	89.65
30	60.96	3.69	81.28	78.74	86.36	93.87
31	57.57	2.98	78.74	76.20	83.82	95.25
32	70.27	6.04	93.98	99.06	101.60	111.04
33	64.35	5.18	78.74	78.74	83.82	91.11
34	82.13	7.58	83.82	86.36	88.90	85.89
35	61.81	4.43	88.90	93.98	96.52	109.06
36	59.27	4.65	86.36	88.90	86.36	105.83
37	71.97	8.17	66.04	66.04	71.12	79.91
38	60.96	4.21	81.28	88.90	96.52	107.84
39	67.73	5.98	71.12	76.20	86.36	97.58
40	71.12	5.77	78.74	78.74	86.36	89.96

ID#	SEBT_Average_ Ant_L_Absolute	SEBT_Ant_ L_MaxD_Scaled	SEBT_ L_Post1	SEBT_ L_Post2	SEBT_ L_Post3	SEBT_Post_ L_MaxD%
41	65.19	3.63	81.28	81.28	83.82	87.31
42	62.65	5.23	68.58	71.12	76.20	89.65
43	61.81	4.79	53.34	55.88	63.50	74.27
44	61.81	6.53	63.50	66.04	68.58	91.44
45	45.72	1.15	58.42	68.58	68.58	78.83
46	60.11	4.02	68.58	71.12	76.20	87.09
47	60.96	4.79	53.34	55.88	60.96	71.30
48	70.27	6.87	73.66	76.20	76.20	89.65
49	60.96	4.87	63.50	60.96	63.50	74.71
50	66.04	6.62	63.50	71.12	71.12	88.35
51	61.81	4.87	73.66	71.12	76.20	89.65
52	73.66	6.15	73.66	76.20	76.20	82.38
53	62.65	5.40	55.88	66.04	68.58	84.15
54	59.27	3.89	68.58	71.12	71.12	80.36
55	57.57	4.07	60.96	55.88	58.42	73.01
56	75.35	6.93	63.50	73.66	76.20	84.20
57	55.88	4.73	60.96	66.04	63.50	80.05
58	75.35	9.57	68.58	78.74	83.82	96.90
59	64.35	5.21	60.96	50.80	55.88	70.88
62	63.50	4.92	55.88	60.96	63.50	72.16
63	60.96	4.44	60.96	68.58	71.12	80.82
64	69.43	7.02	76.20	71.12	81.28	93.43
65	66.89	5.52	76.20	78.74	81.28	89.81
66	65.19	4.02	71.12	71.12	73.66	78.36
67	69.43	7.25	81.28	76.20	73.66	93.97
68	65.19	7.77	60.96	73.66	73.66	93.83
69	68.58	6.34	68.58	73.66	78.74	90.51
70	57.57	3.55	73.66	76.20	73.66	85.62
71	59.27	4.31	73.66	73.66	73.66	86.15
72	73.66	6.37	83.82	83.82	81.28	86.86
73	61.81	3.90	63.50	68.58	66.04	75.36
74	64.35	7.10	71.12	71.12	73.66	87.69
75	54.19	3.70	60.96	60.96	60.96	73.89
76	61.81	4.94	71.12	73.66	73.66	87.17
77	70.27	6.06	93.98	101.60	96.52	112.89
78	59.27	4.65	81.28	76.20	76.20	93.97
79	61.81	5.01	60.96	60.96	66.04	78.62
80	55.03	5.54	55.88	58.42	53.34	75.87

ID#	SEBT_Average_ Ant_L_Absolute	SEBT_Ant_ L_MaxD_Scaled	SEBT_ L_Post1	SEBT_ L_Post2	SEBT_ L_Post3	SEBT_Post_ L_MaxD%
81	60.96	5.59	71.12	66.04	71.12	85.17
82	55.03	3.02	73.66	71.12	71.12	87.69
83	71.97	7.55	71.12	73.66	73.66	87.69
84	63.50	7.10	78.74	73.66	78.74	93.74
85	66.89	3.76	83.82	81.28	83.82	84.67
86	68.58	7.64	78.74	78.74	81.28	95.62
87	57.57	4.22	73.66	71.12	73.66	85.65
88	71.12	5.97	73.66	71.12	73.66	84.18
89	54.19	3.43	68.58	68.58	71.12	84.17
90	51.65	3.45	68.58	68.58	68.58	85.19
91	63.50	5.07	68.58	71.12	71.12	81.75
92	64.35	4.44	68.58	73.66	73.66	80.50
93	60.11	5.01	66.04	71.12	76.20	90.71
94	66.89	6.03	66.04	68.58	68.58	81.64
96	70.27	6.91	81.28	86.36	86.36	94.90
97	68.58	5.48	86.36	86.36	91.44	97.28
98	66.89	5.63	81.28	81.28	81.28	90.31
99	70.27	6.63	71.12	71.12	71.12	79.91
100	60.11	4.09	68.58	68.58	68.58	78.83

ID#	SEBT_L_Med1	SEBT_L_Med2	SEBT_L_Med3	SEBT_Med_L_MaxD%	SEBT_ L_R_Ant_Average	SEBT_Mean_RA_LA_Scaled
1	73.66	73.66	76.20	86.59	6.50	6.56
2	88.90	93.98	81.28	103.27	3.83	3.91
3	96.52	101.60	93.98	112.89	7.43	7.33
4	78.74	86.36	88.90	92.60	4.48	4.60
5	86.36	88.90	76.20	95.08	6.04	6.07
6	63.50	60.96	60.96	83.55	5.35	5.28
7	81.28	93.98	88.90	105.01	6.46	6.43
8	76.20	78.74	81.28	99.12	8.92	8.86
9	86.36	76.20	83.82	95.96	5.58	5.60
11	81.28	86.36	88.90	107.11	6.56	6.63
12	78.74	86.36	88.90	99.89	5.35	5.48
13	81.28	81.28	86.36	95.96	5.81	5.83
14	71.12	73.66	73.66	85.65	4.75	4.92
15	78.74	81.28	83.82	98.04	6.62	6.68
16	76.20	78.74	73.66	94.87	4.06	4.14
17	99.06	101.60	99.06	104.21	6.34	6.34
18	81.28	88.90	96.52	108.45	6.77	6.74
19	71.12	78.74	73.66	88.47	5.12	5.04
20	60.96	73.66	71.12	92.65	2.95	2.80
21	93.98	86.36	99.06	104.83	5.95	5.99
22	76.20	81.28	78.74	86.47	4.08	4.20
23	73.66	76.20	76.20	85.62	5.38	5.39
25	96.52	96.52	99.06	113.86	5.82	5.66
26	78.74	81.28	83.82	91.11	3.22	3.14
27	93.98	104.14	109.22	117.44	5.65	5.51
28	96.52	99.06	101.60	103.67	4.01	3.89
29	86.36	88.90	83.82	104.59	3.93	3.80
30	96.52	96.52	91.44	104.91	3.95	3.83
31	83.82	88.90	86.36	101.02	3.85	4.03
32	96.52	99.06	101.60	111.04	7.25	7.01
33	73.66	83.82	88.90	96.63	4.88	4.73
34	91.44	91.44	101.60	98.16	6.67	6.51
35	86.36	99.06	104.14	117.67	5.54	5.35
36	86.36	88.90	86.36	105.83	4.27	4.17
37	96.52	104.14	101.60	117.01	6.79	6.64
38	86.36	96.52	99.06	110.68	3.81	3.74
39	83.82	91.44	88.90	103.32	5.63	5.51
40	101.60	109.22	106.68	113.77	5.15	5.05

ID#	SEBT_ L_Med1	SEBT_ L_Med2	SEBT_ L_Med3	SEBT_Med_ L_MaxD%	SEBT_ L_R_ Ant_Average	SEBT_Mean_ RA_LA_Scaled
41	83.82	83.82	86.36	89.96	4.88	4.72
42	76.20	76.20	78.74	92.64	5.95	5.77
43	71.12	73.66	76.20	89.12	5.11	5.06
44	68.58	73.66	78.74	104.99	7.84	7.83
45	63.50	60.96	63.50	72.99	1.85	1.67
46	76.20	76.20	76.20	87.09	4.29	4.22
47	73.66	71.12	76.20	89.12	4.58	4.54
48	86.36	91.44	91.44	107.58	6.64	6.67
49	73.66	68.58	68.58	86.66	5.15	5.09
50	78.74	81.28	78.74	100.97	6.14	6.18
51	76.20	83.82	86.36	101.60	5.07	5.04
52	88.90	83.82	83.82	96.11	6.55	6.56
53	76.20	76.20	78.74	96.61	5.70	5.70
54	78.74	83.82	88.90	100.45	4.77	4.66
55	71.12	71.12	68.58	85.17	4.21	4.15
56	83.82	76.20	78.74	92.62	6.99	7.02
57	71.12	76.20	78.74	95.44	4.70	4.60
58	78.74	83.82	76.20	96.90	6.87	6.95
59	76.20	78.74	76.20	91.56	4.91	4.90
62	73.66	78.74	73.66	89.48	3.84	3.85
63	81.28	81.28	81.28	92.36	4.46	4.40
64	83.82	88.90	93.98	108.02	5.39	5.43
65	76.20	83.82	86.36	95.43	5.83	6.10
66	83.82	86.36	86.36	91.87	3.54	3.65
67	73.66	71.12	76.20	88.09	7.31	7.65
68	81.28	78.74	78.74	103.54	7.36	7.68
69	76.20	76.20	81.28	93.43	6.37	6.63
70	78.74	81.28	78.74	91.33	3.03	3.14
71	86.36	88.90	88.90	103.98	5.54	5.84
72	88.90	91.44	88.90	94.76	5.47	5.69
73	86.36	78.74	81.28	94.90	4.50	4.70
74	83.82	83.82	91.44	108.86	7.02	7.38
75	71.12	66.04	68.58	86.21	3.68	3.60
76	73.66	76.20	78.74	93.18	4.26	4.25
77	93.98	104.14	106.68	118.53	6.30	6.29
78	81.28	88.90	88.90	102.77	3.99	3.93
79	83.82	78.74	78.74	99.79	4.35	4.34
80	66.04	68.58	63.50	89.06	5.60	5.88

ID#	SEBT_ L_Med1	SEBT_ L_Med2	SEBT_ L_Med3	SEBT_Med_ L_MaxD%	SEBT_ L_R_ Ant_Average	SEBT_Mean_ RA_LA_Scaled
81	76.20	73.66	76.20	91.26	4.85	5.04
82	81.28	81.28	83.82	99.79	3.89	4.07
83	81.28	78.74	78.74	96.76	7.90	7.95
84	83.82	91.44	93.98	111.88	6.78	6.57
85	91.44	86.36	83.82	92.36	4.67	4.52
86	76.20	83.82	86.36	101.60	7.94	7.71
87	81.28	81.28	83.82	97.47	3.16	3.11
88	78.74	81.28	83.82	95.79	7.15	7.15
89	68.58	76.20	73.66	90.18	2.95	3.11
90	63.50	68.58	68.58	85.19	3.53	3.73
91	76.20	76.20	76.20	87.59	4.66	4.69
92	78.74	73.66	73.66	86.05	4.50	4.45
93	78.74	78.74	78.74	93.74	5.14	5.27
94	73.66	73.66	73.66	87.69	6.33	6.30
96	83.82	83.82	86.36	94.90	7.00	6.78
97	91.44	96.52	101.60	108.09	5.79	5.62
98	83.82	83.82	83.82	93.13	5.83	6.09
99	83.82	88.90	88.90	99.89	5.97	5.85
100	76.20	76.20	73.66	87.59	4.91	5.06

ID#	NEW_Composite_Mean_40	Composite_mean_50_VO2Max	THD_R1	THD_R2	THD_R3
1	22.96	28.55	391.16	431.80	408.94
2	20.50	27.92	396.24	378.46	416.56
3	23.69	28.46	414.02	429.26	436.88
4	13.50	17.25	355.60	381.00	363.22
5	20.59	24.34	388.62	414.02	388.62
6	21.39	27.89	388.62	421.64	401.32
7	20.53	25.61	378.46	421.64	401.32
8	20.01	25.08	353.06	368.30	378.46
9	19.42	27.04	464.82	457.20	459.74
11	23.90	26.43	408.94	416.56	419.10
12	19.65	23.20	449.58	467.36	434.34
13	22.68	29.18	469.90	490.22	469.90
14	19.33	20.94	381.00	375.92	373.38
15	22.29	27.88	383.54	381.00	436.88
16	20.12	23.67	335.28	353.06	327.66
17	21.34	25.91	406.40	454.66	464.82
18	21.32	25.28	337.82	381.00	386.08
19	19.88	26.38	370.84	383.54	378.46
20	12.29	16.24	345.44	337.82	340.36
21	18.63	21.67	342.90	375.92	421.64
22	18.56	23.33	317.50	347.98	317.50
23	20.63	27.13	449.58	497.84	490.22
25	23.34	30.65	601.98	627.38	670.56
26	20.37	25.74	594.36	601.98	599.44
27	22.26	28.73	701.04	708.66	731.52
28	21.06	27.95	619.76	627.38	660.40
29	21.28	25.19	515.62	513.08	518.16
30	22.27	29.99	619.76	698.50	701.04
31	18.03	23.33	640.08	596.90	655.32
32	23.28	28.58	701.04	693.42	668.02
33	25.33	32.56	685.80	688.34	683.26
34	24.74	31.70	647.70	591.82	645.16
35	20.44	24.76	581.66	553.72	619.76
36	23.52	31.38	645.16	637.54	660.40
37	22.46	27.13	571.50	576.58	574.04
38	20.23	24.63	612.14	629.92	645.16
39	24.42	28.20	647.70	640.08	645.16
40	22.97	28.40	574.04	576.58	609.60

ID#	NEW_Composite_ Mean_40	Composite_mean_ 50_VO2Max	THD_R1	THD_R2	THD_R3
41	21.06	24.90	586.74	629.92	601.98
42	25.92	31.15	523.24	505.46	535.94
43	20.52	25.50	424.18	391.16	414.02
44	22.04	27.01	411.48	431.80	431.80
45	15.94	19.70	378.46	353.06	365.76
46	19.96	23.92	429.26	431.80	429.26
47	19.36	23.21	439.42	436.88	429.26
48	28.56	32.31	510.54	518.16	553.72
49	27.23	32.72	411.48	426.72	398.78
50	23.59	30.81	426.72	434.34	449.58
51	23.25	31.07	431.80	469.90	457.20
52	25.27	28.71	431.80	444.50	419.10
53	22.95	28.44	472.44	464.82	492.76
54	21.98	28.78	497.84	500.38	505.46
55	23.82	27.37	472.44	482.60	502.92
56	26.23	30.19	378.46	378.46	375.92
57	25.94	33.05	388.62	396.24	406.40
58	20.44	25.41	373.38	398.78	401.32
59	23.92	31.13	375.92	378.46	363.22
62	18.82	22.78	355.60	340.36	365.76
63	17.35	23.54	393.70	391.16	368.30
64	21.62	27.82	406.40	378.46	403.86
65	20.95	26.59	525.78	558.80	558.80
66	18.95	26.05	579.12	604.52	647.70
67	21.71	24.72	472.44	477.52	474.98
68	23.46	26.68	579.12	525.78	548.64
69	19.04	23.23	393.70	388.62	391.16
70	16.91	21.03	541.02	523.24	530.86
71	19.85	24.52	530.86	518.16	548.64
72	21.96	28.02	599.44	622.30	617.22
73	12.03	13.86	284.48	294.64	289.56
74	20.28	24.19	508.00	533.40	520.70
75	16.87	21.44	347.98	353.06	350.52
76	22.31	30.65	436.88	436.88	398.78
77	22.28	29.09	439.42	467.36	469.90
78	21.23	27.52	502.92	439.42	502.92
79	20.05	27.27	416.56	411.48	426.72
80	16.75	19.76	269.24	246.38	259.08

ID#	NEW_Composite_ Mean_40	Composite_mean_ 50_VO2Max	THD_R1	THD_R2	THD_R3
81	22.27	26.94	472.44	474.98	492.76
82	18.48	25.10	563.88	556.26	561.34
83	26.39	32.39	447.04	469.90	464.82
84	18.59	24.09	533.40	543.56	551.18
85	18.51	23.74	571.50	619.76	619.76
86	22.64	27.86	629.92	703.58	640.08
87	23.02	29.83	535.94	543.56	561.34
88	28.35	34.24	454.66	441.96	462.28
89	18.48	25.29	391.16	439.42	403.86
90	17.18	24.80	335.28	335.28	375.92
91	21.18	26.46	378.46	421.64	426.72
92	17.78	22.65	383.54	383.54	419.10
93	25.70	30.98	426.72	497.84	520.70
94	26.79	32.07	487.68	454.66	474.98
96	25.09	32.54	736.60	716.28	754.38
97	25.13	31.19	640.08	624.84	594.36
98	24.54	30.26	670.56	650.24	657.86
99	21.99	29.43	622.30	617.22	589.28
100	19.63	25.73	370.84	360.68	350.52

ID#	THD_L1	THD_L2	THD_L3	THD_Absolute_ Mean	THD_Mean_ Gender_Scaled	THD_R_ MaxD
1	358.14	368.30	365.76	400.05	4.69	431.80
2	396.24	375.92	454.66	435.61	5.58	416.56
3	386.08	411.48	383.54	424.18	5.32	436.88
4	337.82	347.98	337.82	364.49	3.68	381.00
5	381.00	401.32	401.32	407.67	4.85	414.02
6	408.94	391.16	424.18	422.91	5.26	421.64
7	408.94	391.16	424.18	422.91	5.26	421.64
8	350.52	355.60	345.44	367.03	3.74	378.46
9	403.86	408.94	424.18	444.50	5.89	464.82
11	431.80	449.58	429.26	434.34	5.55	419.10
12	381.00	414.02	454.66	461.01	6.32	467.36
13	391.16	411.48	459.74	474.98	6.72	490.22
14	330.20	320.04	353.06	367.03	3.75	381.00
15	406.40	421.64	426.72	431.80	5.52	436.88
16	297.18	297.18	279.40	325.12	2.62	353.06
17	421.64	414.02	419.10	443.23	5.86	464.82
18	406.40	406.40	441.96	414.02	4.97	386.08
19	358.14	444.50	429.26	414.02	4.96	383.54
20	325.12	309.88	335.28	340.36	3.00	345.44
21	391.16	381.00	391.16	406.40	4.83	421.64
22	332.74	419.10	462.28	405.13	4.67	347.98
23	457.20	467.36	464.82	482.60	6.93	497.84
25	652.78	685.80	673.10	678.18	6.59	670.56
26	558.80	604.52	586.74	603.25	5.55	601.98
27	670.56	683.26	693.42	712.47	7.08	731.52
28	571.50	640.08	645.16	652.78	6.24	660.40
29	530.86	530.86	515.62	524.51	4.45	518.16
30	594.36	655.32	640.08	678.18	6.60	701.04
31	655.32	640.08	617.22	655.32	6.27	655.32
32	680.72	670.56	680.72	690.88	6.77	701.04
33	711.20	698.50	670.56	699.77	6.89	688.34
34	614.68	632.46	637.54	642.62	6.10	647.70
35	579.12	533.40	533.40	599.44	5.51	619.76
36	657.86	645.16	675.64	668.02	6.45	660.40
37	497.84	480.06	510.54	543.56	4.74	576.58
38	553.72	568.96	579.12	612.14	5.69	645.16
39	662.94	673.10	670.56	660.40	6.34	647.70
40	510.54	566.42	525.78	588.01	5.35	609.60

ID#	THD_L1	THD_L2	THD_L3	THD_Absolute_Mean	THD_Mean_Gender_Scaled	THD_R_MaxD
41	561.34	614.68	594.36	622.30	5.82	629.92
42	548.64	523.24	604.52	570.23	5.07	535.94
43	383.54	370.84	396.24	410.21	4.94	424.18
44	401.32	388.62	434.34	433.07	5.54	431.80
45	330.20	368.30	345.44	373.38	3.91	378.46
46	386.08	386.08	408.94	420.37	5.21	431.80
47	393.70	381.00	383.54	416.56	5.13	439.42
48	500.38	520.70	548.64	551.18	8.80	553.72
49	464.82	447.04	436.88	445.77	5.86	426.72
50	355.60	353.06	393.70	421.64	5.28	449.58
51	469.90	462.28	467.36	469.90	6.56	469.90
52	401.32	391.16	411.48	427.99	5.43	444.50
53	457.20	487.68	515.62	504.19	7.48	492.76
54	528.32	513.08	553.72	529.59	8.16	505.46
55	482.60	472.44	474.98	492.76	7.20	502.92
56	325.12	373.38	365.76	375.92	3.97	378.46
57	424.18	449.58	467.36	436.88	5.59	406.40
58	421.64	370.84	396.24	411.48	4.93	401.32
59	365.76	320.04	347.98	372.11	3.87	378.46
62	337.82	381.00	358.14	373.38	3.88	365.76
63	355.60	353.06	320.04	374.65	3.97	393.70
64	386.08	388.62	388.62	397.51	4.58	406.40
65	538.48	520.70	541.02	549.91	4.81	558.80
66	601.98	614.68	629.92	638.81	6.05	647.70
67	543.56	510.54	525.78	510.54	4.25	477.52
68	584.20	546.10	561.34	581.66	5.25	579.12
69	408.94	393.70	401.32	401.32	2.74	393.70
70	518.16	528.32	523.24	534.67	4.60	541.02
71	530.86	518.16	523.24	539.75	4.67	548.64
72	556.26	548.64	551.18	589.28	5.37	622.30
73	269.24	259.08	264.16	281.94	1.09	294.64
74	474.98	462.28	474.98	504.19	4.19	533.40
75	317.50	330.20	322.58	341.63	3.04	353.06
76	469.90	449.58	472.44	454.66	6.11	436.88
77	467.36	492.76	490.22	481.33	6.85	469.90
78	378.46	447.04	459.74	481.33	6.91	502.92
79	416.56	416.56	431.80	429.26	5.43	426.72
80	261.62	264.16	259.08	266.70	0.87	269.24

ID#	THD_L1	THD_L2	THD_L3	THD_Absolute_ Mean	THD_Mean_ Gender_Scaled	THD_R_ MaxD
81	337.82	340.36	335.28	416.56	2.99	492.76
82	480.06	477.52	482.60	523.24	4.46	563.88
83	414.02	416.56	431.80	450.85	6.07	469.90
84	553.72	581.66	591.82	571.50	5.10	551.18
85	619.76	601.98	584.20	619.76	5.78	619.76
86	688.34	695.96	718.82	711.20	7.05	703.58
87	541.02	568.96	561.34	565.15	9.17	561.34
88	429.26	429.26	474.98	468.63	6.51	462.28
89	370.84	353.06	373.38	406.40	4.87	439.42
90	386.08	358.14	358.14	381.00	4.10	375.92
91	401.32	378.46	424.18	425.45	5.33	426.72
92	358.14	365.76	350.52	392.43	4.47	419.10
93	492.76	533.40	482.60	527.05	8.12	520.70
94	454.66	444.50	444.50	471.17	6.62	487.68
96	698.50	744.22	751.84	753.11	7.63	754.38
97	566.42	619.76	640.08	640.08	6.06	640.08
98	574.04	657.86	601.98	664.21	6.40	670.56
99	581.66	515.62	553.72	601.98	5.54	622.30
100	353.06	340.36	347.98	361.95	3.60	370.84

ID#	Gender_THD_ R_Scaled	THD_ L_MaxD	Gender_THD_ L_Scaled	DJV_ KSD1	DJV_ KSD2	DJV_ KSD3	HSD
1	5.44	368.30	3.94	17.52	17.13	17.13	21.03
2	4.99	454.66	6.16	16.35	20.25	15.58	25.31
3	5.59	411.48	5.05	22.97	19.47	17.91	22.20
4	3.95	347.98	3.41	11.68	10.12	10.90	23.75
5	4.92	401.32	4.79	18.30	18.30	22.20	23.36
6	5.14	424.18	5.38	11.68	9.35	10.15	18.30
7	5.14	424.18	5.38	11.29	12.07	13.24	21.03
8	3.88	355.60	3.61	13.24	13.63	13.24	22.97
9	6.41	424.18	5.38	9.35	9.35	11.29	17.13
11	5.07	449.58	6.03	20.25	20.64	21.42	27.26
12	6.48	454.66	6.16	10.51	9.35	9.35	20.64
13	7.15	459.74	6.29	17.52	17.13	15.97	20.25
14	3.95	353.06	3.54	18.30	16.35	19.08	23.75
15	5.59	426.72	5.44	15.58	14.80	14.80	22.20
16	3.13	297.18	2.10	24.14	27.26	22.97	19.08
17	6.41	421.64	5.31	13.63	10.51	10.90	21.81
18	4.10	441.96	5.84	17.13	18.30	20.25	20.25
19	4.03	444.50	5.90	14.41	13.63	14.80	22.20
20	2.91	335.28	3.08	12.07	10.90	10.12	19.86
21	5.14	391.16	4.53	14.80	14.80	14.80	24.92
22	2.99	462.28	6.36	21.42	19.86	22.97	23.36
23	7.38	467.36	6.49	8.96	10.12	9.73	20.25
25	6.45	685.80	6.73	42.50	37.50	45.63	26.25
26	5.46	604.52	5.64	40.63	43.75	46.88	29.38
27	7.33	693.42	6.83	26.25	23.75	23.13	26.88
28	6.31	645.16	6.18	27.44	26.83	35.98	25.61
29	4.26	530.86	4.65	36.81	35.58	35.58	27.61
30	6.89	655.32	6.32	29.63	26.54	26.54	25.31
31	6.23	655.32	6.32	17.90	20.37	19.75	20.37
32	6.89	680.72	6.66	22.56	22.56	25.00	23.17
33	6.71	711.20	7.07	39.76	39.16	40.96	24.70
34	6.12	637.54	6.08	31.48	39.51	40.12	24.69
35	5.72	579.12	5.30	16.46	17.07	19.51	25.00
36	6.31	675.64	6.59	26.38	28.22	28.22	23.93
37	5.10	510.54	4.38	46.25	39.38	44.38	23.75
38	6.09	579.12	5.30	28.66	27.44	27.44	31.71
39	6.12	673.10	6.56	36.36	40.00	42.42	23.64
40	5.57	566.42	5.13	40.82	45.92	45.92	24.49

ID#	Gender_THD_R_Scaled	THD_L_MaxD	Gender_THD_L_Scaled	DJV_KSD1	DJV_KSD2	DJV_KSD3	HSD
41	5.87	614.68	5.77	37.76	41.50	36.39	26.19
42	4.51	604.52	5.64	32.31	32.99	31.97	21.09
43	5.22	396.24	4.66	17.13	13.76	16.21	21.71
44	5.44	434.34	5.64	10.09	9.79	10.09	20.80
45	3.88	368.30	3.94	17.74	18.35	11.93	24.46
46	5.44	408.94	4.98	18.04	17.13	17.13	26.91
47	5.66	393.70	4.59	10.70	13.76	13.76	24.46
48	9.01	548.64	8.59	21.41	28.13	22.02	22.32
49	5.29	464.82	6.43	36.70	28.44	34.86	22.02
50	5.96	393.70	4.59	21.41	21.10	18.96	21.71
51	6.56	469.90	6.56	14.07	13.46	13.15	24.16
52	5.81	411.48	5.05	31.19	32.11	33.64	28.75
53	7.23	515.62	7.74	14.68	14.07	15.60	24.46
54	7.60	553.72	8.72	14.07	13.15	13.15	23.24
55	7.52	482.60	6.88	18.96	21.71	21.71	22.02
56	3.88	373.38	4.07	23.24	14.68	17.13	21.41
57	4.70	467.36	6.49	28.44	26.91	25.99	19.88
58	4.55	421.64	5.31	14.98	16.21	15.90	25.38
59	3.88	365.76	3.87	20.80	19.88	18.65	21.41
62	3.51	381.00	4.26	16.21	16.82	14.68	22.63
63	4.32	355.60	3.61	14.29	14.62	15.15	21.11
64	4.70	388.62	4.46	14.42	15.40	13.11	24.25
65	4.84	541.02	4.79	21.95	20.32	23.26	22.94
66	6.12	629.92	5.98	17.53	17.04	17.37	24.58
67	3.67	543.56	4.82	15.40	14.42	18.02	26.54
68	5.13	584.20	5.36	24.25	23.26	21.95	20.64
69	2.46	408.94	3.02	20.97	18.02	24.90	21.30
70	4.59	528.32	4.62	30.15	31.46	30.69	28.18
71	4.70	530.86	4.65	27.52	27.20	26.54	21.30
72	5.76	556.26	4.99	24.90	29.16	26.54	24.90
73	1.04	269.24	1.14	19.33	21.30	19.33	29.49
74	4.48	474.98	3.90	17.37	13.43	16.38	22.28
75	3.13	330.20	2.95	13.76	13.11	11.80	22.28
76	5.59	472.44	6.62	13.11	12.45	13.10	20.32
77	6.56	492.76	7.15	12.45	12.78	12.45	23.59
78	7.52	459.74	6.29	16.38	20.64	19.01	23.26
79	5.29	431.80	5.57	10.81	12.78	10.49	20.64
80	0.67	264.16	1.08	23.59	19.33	21.95	22.61

ID#	Gender_THD_ R_Scaled	THD_ L_MaxD	Gender_THD_ L_Scaled	DJV_ KSD1	DJV_ KSD2	DJV_ KSD3	HSD
81	3.89	340.36	2.10	33.42	33.75	34.07	22.28
82	4.92	482.60	4.00	20.64	21.95	21.62	24.90
83	6.56	431.80	5.57	26.87	24.58	25.56	22.61
84	4.73	591.82	5.47	23.81	23.13	24.83	26.87
85	5.72	619.76	5.84	20.07	26.87	24.15	27.55
86	6.93	718.82	7.17	16.67	17.69	17.01	21.43
87	9.24	568.96	9.11	21.43	25.51	18.03	26.19
88	6.33	474.98	6.69	25.17	28.23	27.21	23.47
89	5.66	373.38	4.07	15.65	13.61	14.97	27.21
90	3.80	386.08	4.39	14.29	16.33	17.01	24.15
91	5.29	424.18	5.38	14.97	11.90	16.33	26.53
92	5.07	365.76	3.87	16.67	17.01	16.67	25.17
93	8.05	533.40	8.20	18.71	19.73	17.01	23.13
94	7.08	454.66	6.16	16.67	16.33	18.03	26.19
96	7.66	751.84	7.61	34.35	34.69	35.37	23.81
97	6.01	640.08	6.11	40.14	42.18	37.76	25.17
98	6.45	657.86	6.35	19.73	26.87	21.43	24.49
99	5.76	581.66	5.33	24.49	25.17	25.51	24.83
100	3.65	353.06	3.54	19.73	21.09	21.43	27.55

ID#	Mean_Absolute_ Avg_KSD	Mean_Absolute_ KSD_Scaled	Gender_Absolute_ KSD_scaled	Normalized_ KSD1
1	17.26	5.75	5.41	0.82
2	17.39	5.80	5.45	0.69
3	20.12	6.82	6.22	0.91
4	10.90	3.37	3.60	0.46
5	19.60	6.63	6.07	0.84
6	10.39	3.18	3.46	0.57
7	12.20	3.99	3.97	0.58
8	13.37	4.30	4.30	0.58
9	10.00	3.43	3.34	0.58
11	20.77	6.16	6.40	0.76
12	9.74	2.94	3.27	0.47
13	16.87	5.61	5.30	0.83
14	17.91	6.00	5.59	0.75
15	15.06	4.71	4.78	0.68
16	24.79	8.58	7.55	1.30
17	11.68	3.85	3.82	0.54
18	18.56	6.24	5.78	0.92
19	14.28	4.51	4.56	0.64
20	11.03	3.69	3.64	0.56
21	14.80	4.83	4.71	0.59
22	21.42	7.31	6.59	0.92
23	9.60	2.89	3.23	0.47
25	41.88	7.04	7.63	1.60
26	43.75	7.38	7.96	1.49
27	24.38	3.90	4.61	0.91
28	30.08	4.93	5.59	1.17
29	35.99	5.99	6.61	1.30
30	27.57	4.48	5.16	1.09
31	19.34	4.39	3.73	0.95
32	23.37	3.72	4.43	1.01
33	39.96	6.70	7.30	1.62
34	37.04	6.18	6.80	1.50
35	17.68	2.70	3.45	0.71
36	27.61	4.48	5.16	1.15
37	43.34	7.31	7.89	1.82
38	27.85	4.53	5.21	0.88
39	39.59	6.63	7.24	1.67
40	44.22	7.46	8.04	1.81

ID#	Mean_Absolute_ Avg_KSD	Mean_Absolute_ KSD_Scaled	Gender_Absolute_ KSD_scaled	Normalized_ KSD1
41	38.55	6.45	7.06	1.47
42	32.42	5.35	6.00	1.54
43	15.70	4.87	4.96	0.72
44	9.99	3.43	3.34	0.48
45	16.01	4.95	5.05	0.65
46	17.43	5.31	5.46	0.65
47	12.74	4.12	4.12	0.52
48	23.85	6.94	7.28	1.07
49	33.33	9.34	9.97	1.51
50	20.49	6.09	6.33	0.94
51	13.56	4.33	4.36	0.56
52	32.31	9.08	9.68	1.12
53	14.78	4.64	4.70	0.60
54	13.46	4.30	4.33	0.58
55	20.79	6.16	6.41	0.94
56	18.35	5.54	5.72	0.86
57	27.11	7.76	8.21	1.36
58	15.70	4.87	4.96	0.62
59	19.78	5.90	6.12	0.92
62	15.90	5.25	5.02	0.70
63	14.69	4.62	4.68	0.70
64	14.31	4.52	4.57	0.59
65	21.84	5.12	4.17	0.95
66	17.31	3.80	3.38	0.70
67	15.95	3.40	3.15	0.60
68	23.15	5.50	4.39	1.12
69	21.30	4.96	4.07	1.00
70	30.77	7.72	5.71	1.09
71	27.09	6.64	5.07	1.27
72	26.87	6.58	5.04	1.08
73	19.99	4.58	3.85	0.68
74	15.73	3.33	3.11	0.71
75	12.89	4.16	4.17	0.58
76	12.89	4.16	4.16	0.63
77	12.56	4.08	4.07	0.53
78	18.68	5.63	5.81	0.80
79	11.36	3.77	3.73	0.55
80	21.62	5.05	4.13	0.96

ID#	Mean_Absolute_ Avg_KSD	Mean_Absolute_ KSD_Scaled	Gender_Absolute_ KSD_scaled	Normalized_ KSD1
81	33.75	8.58	6.23	1.51
82	21.40	4.99	4.09	0.86
83	25.67	7.40	7.80	1.14
84	23.92	3.82	4.53	0.89
85	23.70	3.78	4.49	0.86
86	17.12	2.60	3.35	0.80
87	21.66	6.38	6.66	0.83
88	26.87	7.70	8.14	1.14
89	14.74	4.81	4.69	0.54
90	15.88	5.24	5.01	0.66
91	14.40	4.68	4.59	0.54
92	16.78	5.15	5.27	0.67
93	18.48	6.21	5.75	0.80
94	17.01	5.66	5.34	0.65
96	34.80	5.77	6.41	1.46
97	40.03	6.71	7.31	1.59
98	22.68	5.36	4.31	0.93
99	25.06	4.03	4.72	1.01
100	20.75	7.06	6.40	0.75

ID#	Normalized_ KSD	Gender_ NKSD_Scaled	MSFT_ Level	MSFT_ Shuttle	MSFT_ 20m	MSFT_ VO2_Max
1	82.07	5.84	6	2	6.2	33.60
2	68.72	4.96	7	10	8	39.60
3	90.62	6.41	5	4	5.4	31.20
4	45.89	3.46	4	4	4.4	28.10
5	83.90	5.97	4	4	4.4	28.10
6	56.79	4.18	7	1	7.1	36.60
7	58.01	4.26	5	7	5.7	32.20
8	58.21	4.27	5	7	5.7	32.20
9	58.36	4.28	8	2	8.2	40.20
11	76.19	5.46	3	2	3.2	24.60
12	47.17	3.54	4	2	4.2	27.40
13	83.33	5.93	7	1	7.1	36.60
14	75.41	5.41	2	3	2.3	22.10
15	67.84	4.91	6	2	6.2	33.60
16	129.93	9.00	4	2	4.2	27.40
17	53.55	3.96	5	2	5.2	30.50
18	91.65	6.48	4	6	4.6	28.80
19	64.32	4.67	7	1	7.1	36.60
20	55.54	4.10	4	6	4.6	28.80
21	59.39	4.35	3	7	3.7	26.30
22	91.68	6.48	5	4	5.4	31.20
23	47.42	3.56	7	1	7.1	36.60
25	159.53	7.25	11	10	12	52.90
26	148.92	6.79	9	2	9.2	43.80
27	90.69	4.23	10	8	10.8	49.00
28	117.47	5.41	11	4	11.4	51.10
29	130.35	5.97	7	1	7.1	36.60
30	108.93	5.03	12	6	12.6	55.30
31	94.94	4.42	9	1	9.1	43.40
32	100.88	4.68	8	11	9.1	43.10
33	161.78	7.35	11	9	11.9	52.60
34	150.01	6.83	11	5	11.5	51.40
35	70.72	3.35	7	7	7.7	38.60
36	115.36	5.31	12	8	12.8	55.90
37	182.47	8.26	8	2	8.2	40.20
38	87.82	4.10	7	8	7.8	38.90
39	167.48	7.60	6	9	6.9	36.00
40	180.56	8.18	9	3	9.3	44.10

ID#	Normalized_ KSD	Gender_ NKSD_Scaled	MSFT_ Level	MSFT_ Shuttle	MSFT_ 20m	MSFT_ VO2_Max
41	147.19	6.71	6	10	7	36.30
42	153.74	7.00	8	10	9	42.80
43	72.32	5.20	5	6	5.6	31.90
44	48.03	3.60	5	6	5.6	31.90
45	65.44	4.75	4	4	4.4	28.10
46	64.78	4.71	4	6	4.6	28.80
47	52.09	3.87	4	5	4.5	28.40
48	106.87	7.48	4	4	4.4	28.10
49	151.38	10.41	6	1	6.1	33.30
50	94.38	6.66	7	8	7.8	38.90
51	56.13	4.13	8	4	8.4	40.90
52	112.39	7.84	4	1	4.1	27.00
53	60.44	4.42	6	1	6.1	33.30
54	57.90	4.25	7	4	7.4	37.60
55	94.43	6.66	4	2	4.2	27.40
56	85.71	6.08	4	6	4.6	28.80
57	136.38	9.42	7	7	7.7	38.60
58	61.85	4.51	5	6	5.6	31.90
59	92.37	6.52	7	8	7.8	38.90
62	70.28	5.07	4	6	4.6	28.80
63	69.57	5.02	6	8	6.8	35.60
64	59.01	4.32	6	8	6.8	35.60
65	95.22	4.43	9	6	9.6	45.00
66	70.44	3.34	11	7	11.7	52.00
67	60.09	2.89	5	8	5.8	32.60
68	112.18	5.17	6	1	6.1	33.30
69	99.98	4.64	7	5	7.5	37.90
70	109.18	5.04	7	4	7.4	37.60
71	127.17	5.83	8	2	8.2	40.20
72	107.90	4.99	10	2	10.2	47.20
73	67.77	3.22	4	1	4.1	27.00
74	70.59	3.35	7	1	7.1	36.60
75	57.85	4.25	5	2	5.2	30.20
76	63.42	4.62	8	9	8.9	42.50
77	53.24	3.94	7	4	7.4	37.60
78	80.30	5.73	6	9	6.9	36.00
79	55.04	4.06	7	8	7.8	38.90
80	95.64	4.45	5	8	5.8	32.60

ID#	Normalized_ KSD	Gender_ NKSD_Scaled	MSFT_ Level	MSFT_ Shuttle	MSFT_ 20m	MSFT_ VO2_Max
81	151.47	6.90	8	2	8.2	40.20
82	85.96	4.02	10	10	11	49.60
83	113.53	7.92	6	6	6.6	34.90
84	89.03	4.16	9	4	9.4	44.40
85	86.01	4.02	8	10	9	42.80
86	79.90	3.76	8	10	9	42.80
87	82.69	5.89	7	4	7.4	37.60
88	114.49	7.98	6	5	6.5	34.60
89	54.18	4.01	7	4	7.4	37.60
90	65.74	4.77	8	2	8.2	40.20
91	54.28	4.01	5	9	5.9	32.90
92	66.68	4.83	5	5	5.5	31.60
93	79.91	5.70	5	9	5.9	32.90
94	64.95	4.72	5	9	5.9	32.90
96	146.17	6.67	11	12	12.2	53.50
97	159.03	7.23	10	2	10.2	47.20
98	92.60	4.31	9	7	9.7	45.30
99	100.91	4.68	12	2	12.2	54.10
100	75.32	5.40	6	7	6.7	35.30

ID#	Gender_MSFT_ Scaled_20m	Gender_MSFT_ Scaled_VO2Max	Time_ To_Fatigue	SEBT_Difference_ Rant_Lant(cm)	Injured_ vs_Control
1	5.58	5.59	5.50	2.89	0
2	7.42	7.54	7.20	4.49	1
3	4.77	4.81	4.33	6.11	1
4	3.75	3.80	3.33	0.88	1
5	3.75	3.80	3.33	0.82	0
6	6.50	6.56	6.30	11.14	0
7	5.08	5.14	4.72	3.26	0
8	5.08	5.14	4.72	3.10	1
9	7.62	7.73	7.53	8.47	0
11	2.53	2.67	2.08	11.73	0
12	3.55	3.58	3.00	4.76	1
13	6.50	6.56	6.17	2.40	0
14	1.62	1.86	1.33	5.11	0
15	5.58	5.59	5.20	10.40	0
16	3.55	3.58	3.00	4.08	0
17	4.57	4.58	4.25	2.61	0
18	3.96	4.03	3.50	2.85	0
19	6.50	6.56	6.17	4.75	1
20	3.96	4.03	3.50	7.82	1
21	3.04	3.22	2.83	0.09	1
22	4.77	4.81	4.33	0.00	1
23	6.50	6.56	6.30	4.76	1
25	7.31	7.32	10.75	0.00	0
26	5.37	5.42	8.70	0.35	0
27	6.47	6.51	9.75	2.73	0
28	6.89	6.94	10.00	2.07	0
29	3.91	3.92	6.32	3.60	0
30	7.72	7.82	11.97	2.20	0
31	5.30	5.34	8.43	4.81	0
32	5.30	5.28	8.38	5.97	1
33	7.24	7.26	10.50	2.59	0
34	6.96	7.01	10.08	5.29	0
35	4.33	4.34	6.75	7.09	0
36	7.86	7.94	12.25	3.20	0
37	4.67	4.67	7.43	6.66	0
38	4.40	4.40	7.00	4.17	1
39	3.77	3.80	6.28	6.70	0
40	5.43	5.49	8.83	6.95	0

ID#	Gender_MSFT_ Scaled_20m	Gender_MSFT_ Scaled_VO2Max	Time_ To_Fatigue	SEBT_Difference_ Rant_Lant(cm)	Injured_ vs_Control
41	3.84	3.86	6.32	3.69	0
42	5.23	5.22	8.50	2.42	0
43	4.97	5.04	5.00	0.42	0
44	4.97	5.04	5.10	3.93	0
45	3.75	3.80	3.65	8.15	1
46	3.96	4.03	4.17	0.39	0
47	3.85	3.90	3.75	3.39	0
48	3.75	3.80	3.83	5.02	0
49	5.48	5.49	5.33	1.00	0
50	7.21	7.31	7.08	9.47	0
51	7.82	7.96	7.83	2.86	1
52	3.45	3.45	3.50	3.62	0
53	5.48	5.49	5.33	4.63	1
54	6.81	6.89	6.40	7.07	0
55	3.55	3.58	3.32	0.60	0
56	3.96	4.03	4.17	4.22	0
57	7.11	7.21	7.25	5.94	0
58	4.97	5.04	5.00	12.72	1
59	7.21	7.31	7.08	5.47	0
62	3.96	4.03	4.17	9.62	0
63	6.20	6.24	6.05	0.00	0
64	6.20	6.24	6.05	12.14	0
65	5.64	5.67	9.07	3.74	0
66	7.10	7.13	11.10	5.94	1
67	3.01	3.09	5.17	2.94	0
68	3.22	3.24	5.42	1.63	0
69	4.19	4.19	6.92	3.38	0
70	4.12	4.13	6.80	0.95	0
71	4.67	4.67	7.63	12.29	0
72	6.06	6.13	9.73	3.99	1
73	1.83	1.92	3.50	2.58	1
74	3.91	3.92	6.47	9.52	0
75	4.57	4.49	4.47	0.40	0
76	8.33	8.48	8.27	9.89	0
77	6.81	6.89	6.65	0.51	1
78	6.30	6.37	6.25	1.56	0
79	7.21	7.31	7.07	7.63	0
80	3.01	3.09	5.17	6.13	0

ID#	Gender_MSFT_ Scaled_20m	Gender_MSFT_ Scaled_VO2Max	Time_ To_Fatigue	SEBT_Difference_ Rant_Lant(cm)	Injured_ vs_Control
81	4.67	4.67	7.63	3.04	0
82	6.61	6.63	10.55	3.24	1
83	5.99	6.01	5.82	4.06	0
84	5.50	5.55	8.73	4.03	0
85	5.23	5.22	8.50	4.28	1
86	5.23	5.22	8.50	1.51	0
87	6.81	6.89	5.78	5.91	0
88	5.89	5.92	5.50	0.46	0
89	6.81	6.89	5.78	1.38	0
90	7.62	7.73	7.50	4.21	0
91	5.28	5.36	5.12	5.29	0
92	4.87	4.94	4.80	2.24	0
93	5.28	5.36	5.12	3.45	0
94	5.28	5.36	5.12	4.03	0
96	7.44	7.44	11.53	3.21	0
97	6.06	6.13	9.60	1.80	0
98	5.71	5.74	9.22	2.82	0
99	7.44	7.57	11.97	8.12	0
100	6.09	6.14	5.28	4.06	0