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Relationship of performance on the Sensory Organization Test to landing characteristics

Keywords: postural stability, stop-jump, landing mechanics, sensory organization test, SOT

ABSTRACT:

Background: Jump landing tasks have been used to assess landing characteristics and require significant sensorimotor feedback to maintain functional joint stability (FJS) throughout the task. Postural stability (PS) also requires significant sensorimotor feedback and control and would seemingly involve similar sensory feedback pathways. However, previous literature clarifying the relationship between these two processes, maintaining FJS and PS, is limited. **Participants:** 80 Special Tactics Operators **Methods:** PS was assessed using the Sensory Organization Test (SOT). SOT variables included: Composite, Somatosensory, Visual, Vestibular, and Preference scores. Landing characteristics were assessed using motion analysis and during a double-legged (DLSJ) and single-legged (SLSJ) stop jump task. Pearson's correlation coefficients were calculated to assess the relationship between SOT scores and landing characteristics ($\alpha<.05$) **Results:** For the DLSJ, significant correlations were found between: Composite and peak posterior ground reaction forces (-.257), Vestibular and peak knee abduction moment (-.237), and Preference and initial contact hip flexion (-.297), peak hip flexion (-.249). For the SLSJ, significant correlations were found between: Somatosensory and peak vertical ground reaction forces (-.246); Preference and initial contact hip flexion (-.295), peak hip flexion (-.262). **Conclusions:** The results indicate that the SOT may not be a sensitive enough tool to assess sensorimotor control in a healthy, athletic population.

INTRODUCTION:

Postural stability (PS) can be defined as the ability to sustain the body in equilibrium by maintaining the projected center of mass within the limits of the base of support.(Sell, 2012; Shumway-Cook, 2001) Functional joint stability (FJS) can be defined as the state of a joint remaining in or promptly returning to proper alignment through an equalization of forces.(Riemann & Lephart, 2002a) Both PS and FJS rely on proper sensorimotor control, including acquiring accurate afferent information, efficient central processing, and effective motor responses.(Riemann & Lephart, 2002b) These neuromuscular control mechanisms help maintain PS and FJS through timely activation of dynamic restraints in response to internal and external perturbations.(Riemann & Lephart, 2002b)

One method of measuring PS is the Sensory Organization Test (SOT). The SOT utilizes a support surface embedded with two force plates, both which are motorized and servo-controlled by a computer. The test involves several static and dynamic conditions, during which the participant's sensory environment is perturbed with alterations to their visual field and support surface while they attempt to maintain an upright, standing position. Further, comparisons can be made between performance on combinations of conditions and the overall postural stability score to assess the acuity of the three sensory feedback systems responsible for maintaining postural stability; visual, vestibular, and somatosensory.(Clark & Iltis, 2008) The SOT has been applied as a diagnostic and research measure, assessing healthy patients as well as those with concussion, lower-extremity injury, vestibular disorders, and aging-related dysfunction.(Clark & Iltis, 2008; Guskiewicz, Ross, & Marshall, 2001; Hirsch, Toole, Maitland, & Rider, 2003; Lepers, Bigard, Diard, Gouteyron, & Guezennec, 1997; Patel, Mihalik, Notebaert, Guskiewicz, & Prentice, 2007)

The analysis of biomechanical characteristics used during landing, such as joint angles, external joint moments, and ground reaction forces, can quantify the strategies a person uses to maintain functional joint stability during landing. Dependent on the timing of peak angular displacement or ground reaction forces, these variables are indicative of proper feedback or feedforward output from the sensorimotor system to either correct for external perturbations or plan for them in an attempt to maintain joint alignment. It would seem logical that significant overlap exists between the sensorimotor pathways that govern postural control and biomechanical characteristics during landing, however previous research on the relationship between postural stability and landing biomechanics is limited (Fransz, Huurnink, Kingma, & van Dieen, 2014) and no previous research has assessed the relationship between performance on the SOT and landing biomechanics.

Both poor PS and certain biomechanical landing characteristics have been associated with lower extremity injury risk in athletes in both first-time and secondary injuries.(Hertel, 2008; Hewett et al., 2005) Subsequently a heavy focus is placed on neuromuscular training programs that challenge the sensorimotor system when attempting to prevent, rehabilitate, or treat lower extremity injuries.(Akbari, Ghiasi, Mir, & Hosseinifar, 2015; Hertel, 2008; Lee & Lin, 2008; Walden, Atroshi, Magnusson, Wagner, & Hagglund, 2012) Adding to this evidence is recent research showing that concussion, which leads to a disruption of the sensorimotor system, may increase the propensity for future lower-extremity injury in collegiate and professional athletes.(Brooks et al., 2016; Herman et al., 2016; Lynall, Mauntel, Padua, & Mihalik, 2015) Determining the relationship between overall PS, as assessed by the SOT, and landing biomechanics will help to clarify the common role that the sensorimotor system may play in maintaining FJS of the lower-extremities and PS. Further, since the SOT offers the advantage of being able to assess different sensory feedback systems individually, it will help to clarify the role that different feedback pathways play in successful execution of a stop-jump task.

The purpose of this study is to assess the correlation between landing biomechanics during a double-legged and single-legged stop-jump task and PS measures obtained during the SOT. We hypothesized that there would be significant correlations between favorable performance on the SOT and favorable landing biomechanics. These results will help to clarify the nature of the sensorimotor system's common role in controlling PS and landing biomechanics, and the specific sensory feedback pathways that may play a role proper landing biomechanics.

For clinicians, if these results are in the expected direction they could provide a rationale use of the SOT by clinicians as a tool to assess the health of sensory feedback pathways, as they pertain to proper landing kinematics, in their efforts to rehabilitate/treat and prevent lower extremity injury. Healthy sensory feedback is certainly not the only determinant of proper landing biomechanics. The use of the SOT as an assessment tool could help clinicians determine if postural stability training could help augment training or rehabilitation for a patient with poor biomechanics during landing. Further, these results could provide evidence that neurological injury, in the form of concussion, has an impact on lower extremity injury risk by providing a link between the sensorimotor systems that are disrupted by concussion and those that govern lower-extremity control.

METHODS:

Participants

Data from 80 male Special Tactics Operators [Age= 27 ±4.8 years, Height= 69.6 ±2.4 in, Weight= 83.3 ±8.9 kg, Body Mass Index= 26.6 ±2.2 kg/m^2] participating in an ongoing prospective study was obtained for this analysis. Participants for the prospective study were recruited via posted flyers throughout their respective military base. All participants were currently injury free and medically cleared for full active duty, according to self-report. Written informed consent was obtained for all participants and all study procedures were approved by the Institutional Review Boards at the X and the X.

Instrumentation

All kinematic data was collected using the Vicon 3D Infrared Optical Capture System and Nexus Software (Vicon, Centennial, CO). Two-dimensional coordinate data was collected utilizing eight high-speed (200 Hz) infrared cameras and transferred to the Nexus software system where it was synchronized and computed with anthropometric measures to construct a 3D rigid body model. Ground reaction force data were collected with two Kistler force plates (Type 9286AA, Kistler Instrument Corp, Amherst, NY) at a sampling rate of 1200 Hz. Kinetic and kinematic data were synchronized using Nexus software's Analog Acquisition Module (Vicon, Centennial, CO).

The Neurocom Smart Balance Master System (Neurocom) (Neurocom International Inc., Clackamas, OR) was used in the performance of the SOT. This system includes two force plates embedded in a motorized, servo-controlled platform, as well as a motorized, servo-controlled, artificial surrounding. Both the platform and artificial surrounding rotate about an axis aligned with the center of the participant's malleolus, in the anterior/posterior directions. The two force plates serve to measure the changes in postural sway (sampling rate=100 Hz) produced from the shifting of an individual's center of gravity about their base of support during the performance of the SOT.

Procedures:

All participants completed the SOT, a double-leg stop-jump task (DLSJ) and a single-leg stop-jump task (SLSJ), in this order. Procedures for the SOT were carried out by the manufacturer's instructions (Neurocom International Inc., Clackamas, OR). Participants were first positioned by the tester with one foot on each force plate and their medial malleoli in-line with the platform's axis of rotation and the lateral border of their calcanei separated by a standard distance based on their height. During all conditions of the SOT, participants were asked to stand as still as possible, looking straight ahead and with their hands at their sides. Each condition was tested with three trials, with each trial lasting 20 seconds.

The six conditions of the SOT, as described by Clark et al (Clark & Iltis, 2008), are : 1) eyes open, with no movement of the support surface or visual surround (EO), 2) eyes closed, with no movement of the support surface (EC), 3) eyes open, with a sway-referenced visual surround and no movement of the support surface (EO-SV), 4) eyes open, with a sway-referenced support surface and no movement of the visual surround (EO-SS), 5) eyes closed, with a sway-referenced support surface (EC-SS), 6) eyes open, with both a sway-referenced support surface and a sway-referenced visual surround (EO-SVS). During conditions involving sway in either the support surface or visual surround, the amount of sway provided was in direct proportion to changes in the participant's COG in the anterior/posterior direction.(Clark & Iltis, 2008) For each trial of each condition, an equilibrium score is automatically calculated by Neurocom's software. The equilibrium scores are calculated using the following formula: $\{[12.5°-(COG_{Max}-COG_{Min})]/12.5°\}x100$, where 12.5° is the theoretical maximal sway range in the anterior/posterior directions and COG_{Max} and COG_{Min} are the calculated maximal and minimum sway angles calculated during the trial.

For the SLSJ and DLSJ tasks, participants were first fitted with retro-reflective markers, placed bilaterally on the: anterior superior iliac spine, posterior superior iliac spine, lateral mid-thigh, lateral condyle of the knee, lateral mid-lower leg, lateral malleolus, posterior heel, and second metatarsal. All participants were required to wear spandex shorts and their personal athletic shoes. Before the stop-jumps were performed, a static capture of the marker set was collected with the participant standing upright, their feet hips-width apart, and arms in an anatomical neutral position.

To perform the DLSJ, participants started in a double-leg stance at a distance of 40% of their height from the two force plates. Participants were instructed to: jump towards and land completely on the force plates, landing with one foot on each plate, immediately jump vertically as high as possible. To perform to SLSJ, participants replicated these same procedures with the alteration of jumping with, and landing on, their dominant leg only. Participants were asked to perform at least three practice trials, and then as many warm-up trials as needed were given for each type of jump. Three successful trials were collected for analysis, where the participant landed completely on the force plates and did not pause after the initial landing before performing the vertical jump.

Data Reduction:

The Neurocom software automatically calculates an overall composite equilibrium score (COMP) from the equilibrium scores on each trial, providing a quantitative measure of an individual's PS across the six testing conditions. Neurocom software automatically calculates scores for the visual (VIS), somatosensory (SOM) and vestibular (VES) systems by dividing the composite equilibrium scores from conditions where each sensory feedback system is limited by the composite equilibrium score for the EO condition: VIS= EO-SS condition/ EO condition, SOM= EC condition/ EO condition, VES= EC-SS condition/ EO condition. These ratios are on a scale of 0-100, with 100 signifying perfect performance. Finally, the Neurocom software calculates a Preference score (PREF) with the following formula: (EO-SV+ EO-SVS) / (EC+EC-SS). This score, on a scale of 0-200 with 200 signifying perfect performance, indicates the degree to which an individual relies on visual information to maintain their PS, even when the information is incorrect.

Lower extremity kinematics and kinetics during the stop-jump tasks were processed using Nexus Software (version 1.8.5, Vicon, Centennial, CO) according to the Plug-In Gait biomechanical model (Vicon, Centennial, CO) a modified version of the Newington-Helen Hayes gait model.(Davis, Ounpuu, Tyburski, & Gage, 1991; Kadaba, Ramakrishnan, & Wootten, 1990) Raw kinematic data was first filtered using a Woltring filter routine.(Woltring, 1986) Then, using the static capture as an anatomical reference system, the Plug-in Gait model uses relative Euler rotation angles and inverse dynamics to calculate all joint kinematics and kinetics. Finally, a custom Matlab code (version: R2014a, Matworks Inc., Natick, MA) was used to identify peak variables and variables at initial contact.

These variables included: hip flexion at initial contact, hip abduction at initial contact, knee flexion at initial contact, knee varus at initial contact, ankle flexion at initial contact, peak knee flexion, time to peak knee flexion, peak hip flexion, peak hip abduction, peak knee varus, peak knee abduction moment, peak vertical ground reaction forces (GRF), peak posterior ground reaction forces (GRF), peak proximal anterior tibial shear forces. More favorable landing characteristics are dependent on the variable. Generally, lower hip and knee abduction angles, time to peak knee flexion, hip and knee abduction moments, posterior and vertical GRF, and proximal anterior tibial shear forces are considered more favorable. In contrast, higher hip, knee and ankle flexion angles and knee varus angles are considered more favorable.

All variables were calculated from the participant's dominant leg, defined as the leg they would use to kick a ball, and the average of three successful trial. In cases where variables could not be correctly identified for three successful trials, the variable was dropped for all further analysis. These cases were mainly due to marker dropout, and the highest number of participants that had to be dropped for a given variable was seven.

Data Analysis:

All statistical tests were performed using IBM SPSS Statistics 21 (IBM corp., Armonk, NY). Variables were checked for normality with Shapiro-Wilk tests of normality and visual inspection of histograms, and means, standard deviations and 95% confidence intervals were calculated. Pearson's Correlation Coefficients were calculated to compare the association between COMP, VES, VIS, SOM, and PREF scores from the SOT and stop-jump landing kinematic and kinetic variables. In the case of variables that violated normality, Spearman's Rank Coefficients were utilized. Correlation coefficients were determined to be weak (.10-.29), moderate (.3-.49), and large (>.5) based on guidelines established by Cohen (Cohen, 1988). Significance was set at $\alpha<.05$ for all statistical tests.

RESULTS:

Descriptive statistics for all variables are presented in Tables 1-3. Correlation matrixes for all correlations between SOT variables and biomechanical variables during the DLSJ and SLSJ are presented in Tables 4 and 5 respectively.

Double-Leg Stop-Jump:

The PREF score from the SOT showed significant correlations with hip flexion at initial contact (r=-.297, p=.007) and peak hip flexion (r=-.249, p=.027) during the DLSJ. The VES score from the SOT showed significant correlation to peak knee abduction moment (r=-.237, p=.040) during the DLSJ. The COMP score from the SOT showed significant correlation to peak posterior GRF (r=-.257, p=.025) during the DLSJ. All other correlations were insignificant at α=.05.

Single-Leg Stop-Jump

The PREF score from the SOT showed significant correlations to hip flexion at initial contact (r=-.295, p=.008) and peak hip flexion (r=-.262, p=.024) during the SLSJ. The SOM score from the SOT showed significant correlation to peak vertical GRF (r=-.246, p=.036) during the SLSJ. All other correlations were insignificant at α=.05.

DISCUSSION:

The purpose of this study is to establish the relationships between COMP, VES, SOM and VIS scores on the SOT and landing biomechanics during two stop-jump tasks. While some significant correlations were found, the results of the study showed an overall lack of correlation between performance on the SOT and landing mechanics during the DLSJ and SLSJ tasks. The significant correlations that were found were small and without any identifiable pattern.

Mean SOT scores obtained in this study are similar to those reported for college-aged males by Clark et al.(Clark & Iltis, 2008), but lower than those reported for collegiate athletes. The numbers reported in this study are most similar to those reported by Lepers et al.(Lepers et al., 1997) in well-trained adults, however their sample consisted of only nine participants. Lower extremity biomechanics during the DLSJ and SLSJ tasks are difficult to compare between studies, due to methodological differences in jump-landing tasks, differences in participant characteristics, and a lack of reported data for most biomechanical variables included in this analysis. For example, mean peak knee flexion values reported by Chu et al (Chu et al., 2012) for air assault soldiers performing a drop-landing were much lower (88.6° vs 103.85°) than those found in the current study, even though the studies participant characteristics are similar. The means for biomechanical variables obtained in this study are similar to those typically seen in our lab's previous work with Special Tactics Operators and stop-jump maneuvers.

It is difficult to explain this lack of a relationship between two measures that both rely on significant sensorimotor control, however several likely explanations exist. The first explanation lies in the nature of the two tests used to quantify FJS and PS. The SOT and stop-jump tasks that our participants performed would both be considered dynamic tasks, however the DLSJ and SLSJ are significantly more dynamic in nature. Some would even argue that the SOT is a static task, as the requirement for participants is focused on maintaining a static posture. Several previous studies have shown a lack of relationship between static and dynamic measures of PS, and these studies utilized similar stances (i.e. single-leg or double-leg), whereas one of our jumping tasks (the SLSJ) and the SOT do not.(Fransz et al., 2014; Heebner, Akins, Lephart, & Sell, 2015; Sell, 2012) Further, the stop-jump task requires participants to leave and re-establish their base of support, whereas the base of support remains unchanged during the SOT.

This leads to the likelihood that many of the variables measured during the stop-jump tasks are more dependent on feedforward control whereas SOT performance would be more dependent on sensorimotor feedback.(Horita, Komi, Nicol, & Kyröläinen, 2002; Oberlander, Bruggemann, Hoher, & Karamanidis, 2012) Even peak biomechanical variables may be highly dependent on feedforward control, given that the majority of them occur within 300ms of initial contact.(Chu et al., 2012) The argument could be made that while both the SOT and stop-jumps challenge proprioceptive and neuromuscular abilities, assessing the correlation between these two tasks won't reflect this, given how different the tasks are.

A second possible explanation is that the SOT does not present a challenging enough sensory task for this population. The mean COMP score on the SOT was 78.30, which is well above the "healthy" cut-off of 70.00 provided by the manufacturer (Neurocom International Inc., Clackamas, OR), and the confidence interval about this mean was very small (77.19-79.41). Above the "healthy" cut-off, it is hard to say whether higher scores would have a linear relationship, if any, with the health of an individual's sensorimotor system. Further, Clark et al. (Clark & Iltis, 2008) demonstrated that the SOT was not a challenging enough PS task to elicit differing results in collegiate athletes and inactive, college-aged individuals. Only when head-tilts were added to the normal SOT protocol, i.e. further visual perturbations, were they able to see significant differences between these groups. Special Tactics Operators are often referred to as "tactical athletes", because of the rigorous physical demands of their work and training. So for these participants, the SOT may not have presented a challenging enough sensory task to delineate between participants who demonstrated worse or better landing mechanics during the stop-jump tasks.

In practical terms, this lack of a relationship between performance on these two tasks presents a limitation for clinicians working with healthy patients, as well as those returning from musculoskeletal and neurological injury. Abnormal movement patterns, indicative of altered or deficient sensorimotor control, are commonly cited as predictors of first time and future musculoskeletal injury. (Hewett et al., 2005; Paterno et al., 2010) However, the instrumentation costs, time and expertise required to capture measures of movement patterns are such that they are generally not feasible for a human performance or rehabilitation setting. Therefore, if significant relationships had been established between performance on the SOT and healthy movement patterns, it could have presented the possibility of simplifying assessments of sensorimotor control for these clinicians by use of the SOT.

Related to concussion and other neurological injuries, significant relationships between these two measures would have provided a basis for further investigation into the SOT as a tool to assess the relationship between concussion and future injury to the lower extremities. In these terms, it is still not clear whether the SOT may provide an adequate measure for this population. As described earlier, it may be that the lack of a relationship between the SOT and landing mechanics was simply a function of the SOT not being a challenging enough measure for the population utilized in this study. Likewise, this means that the comparisons were made in healthy individuals, without concussion or other known neurological disorders. Based on both of these factors, further investigation would be required in individuals having recently suffered or with a history of concussion to establish that the SOT is not an adequate measure for characterizing the effects of concussion on lower-extremity sensorimotor control, and subsequent injury, described in previous work.(Brooks et al., 2016; Herman et al., 2016; Lynall et al., 2015)

There are some limitations to the current study. First, prior research has found a learning effect with the SOT, with at least two trials of the SOT needed to obtain a reliable result.(Dickin & Clark, 2007) The current study did not administer multiple trials of the SOT, and therefore did not account for this learning effect. The study demonstrating this effect, however, used a sample of healthy adults and the same effect has never been replicated in athletes, who would most likely be at a higher baseline level for SOT performance. (Wrisley et al., 2007) Secondly, no direct measures of the sensory feedback systems being mentioned so often in this paper were obtained, and we therefore cannot conclusively determine their relationship to either PS or landing biomechanics. The current study was simply meant to be a starting point in exploring these potential relationships and certainly not the definitive end of that exploration.

To conclude, this study demonstrated weak and inconsistent relationships between performance on the SOT and landing mechanics during a DLSJ and SLSJ task. This was in opposition to our hypothesis; that significant correlations would be found between performance on these two tasks. It is believed that this lack of a relationship can be attributed to the SOT not being a challenging enough task to delineate varying levels of postural control in the tactical athlete population. Taking into account the previous findings of Clark et al. (Clark & Iltis, 2008), it is recommended that modifications be made to the normal SOT protocol when being used to assess PS in tactical athletes. For clinicians who work with athletic populations, it would seem that the SOT may not be a sensitive enough tool to assess if sensorimotor training is needed to improve landing biomechanics or PS in the effort to rehabilitate, treat or prevent injury to the lower-extremities. Further, these results should lead clinicians to carefully consider task selection and the type of sensorimotor output a task will elicit (i.e. feedforward versus feedback) when assessing a client’s progression in rehabilitation or neuromuscular training.

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Table 1- SOT Summary Data

	Mean (SD)	95% Confidence Interval
Composite Score	78.3 (5.08)	77.19, 79.41
Somatosensory Score	97.5 (3.36)	96.76, 98.24
Visual Score	89.3 (7.76)	87.6, 91.00
Vestibular Score	69.5 (10.00)	67.65, 72.30
Preference Score	100.3 (7.18)	98.73, 101.87

[a.] SOT= Sensory Organization Test, SD= standard deviation

Table 2- Double-Leg Stop-Jump Summary Data

	N	Mean (SD)	95% Confidence Intervals
Hip Flexion- Initial Contact	79	48.78 (11.59)	46.23, 51.34
Hip Abduction- Initial Contact (º)	79	-3.06 (5.97)	-4.38, -1.75
Knee Flexion- Initial Contact (º)	80	32.48 (10.91)	30.09, 34.87
Knee Valgus- Initial Contact (º)	80	11.23 (7.79)	9.53, 12.94
Ankle Flexion- Initial Contact (º)	79	-7.54 (15.14)	-11.47, -4.46
Knee Flexion- Peak (º)	80	103.85 (16.79)	100.17, 107.53
Time to Peak Knee Flexion (s)	80	.241 (.058)	.229, .254
Hip Flexion- Peak (º)	79	79.12 (13.39)	76.17, 82.07
Hip Abduction- Peak (º)	79	-1.08 (6.35)	-2.48, .32
Knee Valgus- Peak (º)	80	21.91 (11.85)	19.31, 24.50
Knee Abduction Moment- Peak (N)	76	618.25 (366.10)	535.95, 700.55
Vertical GRF (N)	76	195.47 (62.17)	181.49, 209.45
Posterior GRF (N)	76	27.61 (17.92)	23.58, 31.64
Proximal Anterior Tibial Shear Force (N)	76	7.62 (1.70)	7.25, 8.00

a. SD=Standard Deviation, GRF=Ground Reaction Forces, N=Sample Size
b. Negative values indicate extension, valgus, and adduction
c. Joint forces are calculated as external moments

Table 3- SLSJ Summary Data

	N	Mean (SD)	95% Confidence Intervals
Hip Flexion- Initial Contact	76	39.04 (9.84)	7.24, 8.00
Hip Abduction- Initial Contact (º)	74	-5.04 (6.51)	-6.52, -3.56
Knee Flexion- Initial Contact (º)	75	20.40 (7.33)	18.74, 22.06
Knee Valgus- Initial Contact (º)	75	5.50 (5.48)	4.26, 6.74
Ankle Flexion- Initial Contact (º)	74	-13.16 (15.59)	-16.71, -9.61
Knee Flexion- Peak (º)	75	74.03 (10.74)	71.60, 76.46
Time to Peak Knee Flexion (s)	75	.270 (.070)	.254, .286
Hip Flexion- Peak (º)	74	60.64 (11.71)	57.97, 63.31
Hip Abduction- Peak (º)	74	9.32 (7.00)	7.73, 10.92
Knee Valgus- Peak (º)	75	20.29 (10.68)	17.86, 22.71
Knee Abduction Moment- Peak (N)	73	1206.47 (568.09)	1076.16, 1336.79
Vertical GRF (N)	73	294.37 (77.70)	276.55, 312.20
Posterior GRF (N)	73	38.97 (29.40)	32.22, 45.71
Proximal Anterior Tibial Shear Force (N)	73	8.83 (3.12)	8.11, 9.54

a. SD=Standard Deviation, GRF=Ground Reaction Forces, N= Sample Size
b. Negative values indicate extension, valgus, and adduction
c. Joint forces are calculated as external moments

Table 4- Correlations Between SOT Score and Landing Biomechanics for the DLSJ

		HF -IC	**HAB -IC**	**KF -IC**	**KV -IC**	**AF -IC**	**KF -P**	**TTPKF**	**HF -P**	**HAB -P**	**KV -P**	**KAM -P**	**vGRF -P**	**pGRF -P**	**PATSF**
COMP	Coeff:	**.021**	**.046**	**-.006**	**.034**	**.007**	**-.045**	**-.002**	**-.023**	**.055**	**.059**	**-.148**	**-.039**	**-.257***	**-.164**
	Sign:	.856	.687	.957	.767	.949	.693	.985	.839	.629	.601	.202	.740	.025	.156
	N:	80	79	80	80	79	80	80	79	79	80	76	76	76	76
SOM	Coeff.:	**-.046**	**.140**	**-.031**	**-.013**	**-.002**	**.016**	**.029**	**-.081**	**.145**	**-.004**	**-.139**	**-.120**	**-.013**	**-.039**
	Sign:	.685	.220	.782	.910	.985	.889	.798	.477	.202	.975	.232	.303	.908	.738
	N:	80	79	80	80	79	80	80	79	79	80	76	76	76	76
VIS	Coeff.:	**.011**	**.052**	**-.078**	**-.003**	**-.029**	**-.148**	**-.068**	**-.049**	**.059**	**.026**	**-.125**	**.075**	**-.123**	**-.181**
	Sign:	.922	.646	.493	.982	.800	.191	.550	.670	.608	.819	.284	.518	.291	.119
	N:	80	79	80	80	79	80	80	79	79	80	76	76	76	76
VES	Coeff:	**.133**	**.130**	**.155**	**-.088**	**.173**	**.064**	**-.060**	**.117**	**.038**	**-.087**	**-.237***	**-.020**	**-.198**	**-.104**
	Sign:	.238	.255	.169	.440	.128	.572	.599	.304	.740	.442	.040	.863	.086	.371
	N:	80	79	80	80	79	80	80	79	79	80	76	76	76	76
PREF	Coeff:	**-.297***	**-.069**	**-.019**	**.088**	**-.025**	**-.047**	**-.062**	**-.249***	**.006**	**.116**	**-.024**	**.042**	**.042**	**.113**
	Sign:	.007	.544	.866	.435	.826	.679	.587	.027	.957	.305	.839	.721	.716	.330
	N:	80	79	80	80	79	80	80	79	79	80	76	76	76	76

a. *- Denotes statistical significance at α<.05
b. Coeff= Pearson's Correlation Coefficient or Spearman's Rank Coefficient, Sign= Statistical Significance, N= Sample Size
c. HF-IC= Hip Flexion at Initial Contact, HAB-IC= Hip Abduction at Initial Contact, KF-IC= Knee Flexion at Initial Contact, KV-IC=Knee Valgus at Initial Contact AF-IC= Ankle Flexion at Initial Contact, TTPKF= Time to Peak Knee Flexion, HF-P= Peak Hip Flexion, HAB-P= Peak Hip Abduction, KV-P= Peak Knee Valgus, KAM-P= Peak Knee Abduction Moment, vGRF-P= Peak Vertical Ground Reaction Forces, pGRF-P= Peak Posterior Ground Reaction Forces, PATSF= Proximal Anterior Tibial Shear Force
d. Coefficients for AF-IC, KAM-P, vGRF-P, pGRF-P, PATSF, SOM, VIS, and VEST are results of Spearman Rank Correlations

Table 5- Correlations Between SOT Scores and Landing Biomechanics for the SLSJ

		HF -IC	HAB -IC	KF -IC	KV -IC	AF -IC	KF -P	TTPKF	HF -P	HAB -P	KV -P	KAM -P	vGRF -P	pGRF -P	PATSF
COMP	Coeff:	**-.057**	**-.012**	**-.074**	**.015**	**.043**	**-.097**	**-.018**	**0.146**	**-.057**	**-.017**	**-.085**	**-.131**	**-.114**	**-.122**
	Sign:	.617	.922	.529	.898	.714	.409	.879	.215	.628	.886	.476	.268	.337	.303
	N:	80	74	75	75	74	75	75	74	74	75	73	73	73	73
SOM	Coeff.:	**.029**	**-.026**	**.051**	**.130**	**-.128**	**-.092**	**-.075**	**-.146**	**.015**	**-.080**	**-.060**	**-.246***	**-.086**	**-.035**
	Sign:	.796	.823	.664	.266	.278	.433	.523	.215	.901	.493	.615	.036	.472	.769
	N:	80	74	75	75	74	75	75	74	74	75	73	73	73	73
VIS	Coeff.:	**.025**	**-.013**	**-.079**	**-.056**	**.212**	**.038**	**.066**	**-.052**	**-.078**	**-.064**	**.025**	**-.038**	**-.131**	**-.005**
	Sign:	.824	.910	.500	.634	.070	.749	.575	.659	.511	.588	.834	.748	.270	.965
	N:	80	74	75	75	74	75	75	74	74	75	73	73	73	73
VES	Coeff:	**.105**	**.122**	**.110**	**-.065**	**.130**	**.016**	**-.010**	**.056**	**.039**	**-.112**	**-.123**	**-.196**	**-.110**	**.005**
	Sign:	.356	.299	.349	.578	.269	.894	.929	.636	.744	.337	.302	.097	.354	.969
	N:	80	74	75	75	74	75	75	74	74	75	73	73	73	73
PREF	Coeff:	**-.295***	**-.125**	**-.042**	**.070**	**-.025**	**-.014**	**.006**	**-.262***	**-.146**	**.035**	**-.015**	**.097**	**.043**	**-.008**
	Sign:	.008	.290	.719	.548	.835	.905	.959	.024	.213	.764	.897	.413	.721	.949
	N:	80	74	75	75	74	75	75	74	74	75	73	73	73	73

a. *- Denotes statistical significance at $\alpha<.05$
b. Coeff= Pearson's Correlation Coefficient or Spearman's Rank Coefficient, Sign= Statistical Significance, N= Sample Size
c. HF-IC= Hip Flexion at Initial Contact, HAB-IC= Hip Abduction at Initial Contact, KF-IC= Knee Flexion at Initial Contact, KV-IC= Knee Valgus at Initial Contact AF-IC= Ankle Flexion at Initial Contact, TTPKF= Time to Peak Knee Flexion, HF-P= Peak Hip Flexion, HAB-P= Peak Hip Abduction, KV-P= Peak Knee Valgus, KAM-P= Peak Knee Abduction Moment, vGRF-P= Peak Vertical Ground Reaction Forces, pGRF-P= Peak Posterior Ground Reaction Forces, PATSF= Proximal Anterior Tibial Shear Force
d. Coefficients for AF-IC, vGRF-P, pGRF-P, PATSF, VIS, VES, and PREF are results of Spearman Rank Correlations