USING VERTICAL JUMP POWER AND STANDING LONG JUMP POWER TO DETERMINE MUSCLE IMBALANCE

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The purpose of this investigation was to determine the relationship between a ratio between vertical jump (VJ) power and standing long jump (SLJ) power and knee injury risk by using the functional power outputs with information generated from knee isokinetic testing. Medical records along with strength and conditioning testing records of 13 female NCAA-I soccer athletes were examined. Correlation and linear regressions were run to find relationships. The medical records included the isokinetic knee flexion and extension testing. Data from VJ height and SLJ distance were taken from the strength and conditioning data. Using VJ and SLJ power results to determine tendency in muscle dominance would allow development of interventions tailored to decrease the imbalance.

KEY WORDS: soccer, muscle imbalance, females, knee injury risk.

INTRODUCTION: The incidence of injury in women's soccer is 3 times higher in games than in practices and 3 times higher in pre-season practice then during in-season practice(Dick, Putukian, Agel, Evans, & Marshall, 2007). Approximately 70% of all injuries in women's soccer occur to the lower extremity(Dick et al., 2007). Over the years, there has been debate as to why females are more susceptible to lower extremity injury. Commonly reported factors include: structural differences in the knee, ligament size, lower extremity alignment, skill and/or conditioning deficits; strength imbalances, and hormonal influences.

A strength imbalance between the hamstrings and quads increases the risk of injuries, such as muscle strains and ligament sprains. The hamstrings help the ACL prevent the tibia from moving too far forward. Females exhibit muscular imbalance between the hamstrings and quadriceps putting them at risk for ACL injury (Ahmad et al., 2006; Opar & Serpell, 2014). Male athletes activate the hamstrings sooner and more often than female athletes; this predisposes the females to ACL injury (Zebis, Andersen, Ellingsgaard, & Aagaard, 2011). Females muscle activity tends to be the opposite of males (Ahmad et al., 2006; Zebis et al., 2011). A decreased rate of force development during initial movement in female soccer athletes can lead to decreased knee stability (Zebis et al., 2011). Female athletes frequently develop quadriceps dominance; which is an imbalance in the recruitment patterns between the quadriceps and hamstrings (Myer, Ford, & Hewett, 2004). This means the hamstrings are weaker than the quadriceps in females. Weaker muscles fatigue more quickly resulting in greater strength imbalances and injury risk (O'Sullivan, O'Ceallaigh, O'Connell, & Shafat, 2008). Quantifying muscle balance to decrease injury risk can be done through the hamstring-to-quadriceps ratio. A means to test for muscle balance is by using isokinetics. An isokinetic dynamometer is a device controlling the velocity at which users move a limb allowing for evaluation of muscles in concentric and eccentric contractions (Hislop & Perrine, 1967). The isokinetic device challenges muscular force development throughout the range of motion without acceleration occurring (Thistle, 1967). Isokinetic testing produces reliable data when testing simple joints, such as the knee. (Zvijac, Toriscelli, Merrick, Papp, & Kiebzak, 2014) Isokinetic testing is used for injury evaluation, injury prevention and return to play purposes. A test output from the isokinetic testing is the hamstring-to-quadriceps ratio (H:Q ratio).

Practical means to test the functional relationship of the H:Q ratio exist. However, the ability to quantify the relationship has been difficult. Field tests, like the VJ and SLJ, are used to determine power development, athlete development, and quantify training protocol effectiveness. VJ and the SLJ are simple tests. The VJ test measures how high an athlete jumps vertically assessing the ability to generate vertical power. The SLJ tests the horizontally jumping ability of an athlete and assesses horizontal power generating capabilities. An idea exists that a comparison of the power outputs from a VJ and a SLJ gives picture of lower

extremity injury risk (Mann, 2014). Mann states that an individual with higher power output for the VJ when compared to SLJ power is at risk for hamstring and knee injury (Mann, 2014).
The individuals responsible for the health care of athletes need practical means to determine lower extremity injury risk. The ability to compare the relationship of these two commonly used field tests could greatly enhance this practical ability. The purpose of this investigation was to determine the relationship between a calculated ratio between VJ power and SLJ power and the functional power outputs generated from isokinetic knee testing to determine if the ratio is sensitive in determining knee injury risk.

METHODS: Participants of the study were 13 female NCAA-I soccer athletes. The study examined data from testing conducted by sports medicine and strength staff on the athletes prior to beginning an off-season training cycle. The study was approved by the university IRB committee.
Isokinetic testing was completed on a Cybex Humac Norm (Computer Sports Medicine, Inc., Soughton, MA, USA). Testing on the isokinetic device was conducted at 60°/sec and 180°/sec. Vertical jump (VJ) height was determined using a Vertec (Vertec Sports Imports, Hilliard, OH) measuring device. Standing long jump (SLJ) distance was determine through the use of a tape measure. Power and velocity for the VJ and SLJ were determined by using a TENDO Power and Speed Analyzer (TendoSport, Trencin, Slovak Repbulic).Medical records along with strength and conditioning testing records were examined. The medical records included the isokinetic knee flexion and extension testing. Information gathered from the isokinetic testing included: peak torque quadriceps (PTQuad), peak torque hamstrings (PTHam), ratio, Vertical jump (VJ) height, standing long jump (SLJ) distance, peak vertical jump power (PVJP), average vertical jump power (AVJP), average vertical jump velocity (AVJV), peak vertical jump velocity (PVJV), peak vertical jump force (PVJF), peak standing long jump power (PSLJP), average standing long jump power (ASLJP), average standing long jump velocity (ASLJP), peak standing long jump velocity (PSLJV), and peak standing long jump force (PSLJF) comprised the information taken from the strength and conditioning data.
Correlation and linear regressions were run to find relationships between the variables. Significance was set at the .01 level.
PVJP, AVJP, PSLJP, and ASLJP information from the TENDO Power and Speed Analyzer for each athlete were analyzed to form a power ratio between the VJ and the SLJ. A comparison of these numbers helps determine a dynamic means of determining hamstring or quadriceps dominance in an athlete (Mann, 2014). To do this, the peak power and average power for the VJ and the SLJ were normalized using allometric scaling (Jaric, 2002). The AVJP was divided by ASLJP to create the average power ratio. PVJP was divided by PSLJP to create the peak power ratio. The average power ratios and the peak power ratios were then converted to z-scores for analysis from the mean.

RESULTS: No correlations occurred between the power-related variables and the VJ, and the SLJ. Table 1 and Table 2 list the significant correlations between isokinetic test results and the performance tests.

Table 1
Correlation of Vertical Jump and Standing Long Jump to 60°/sec isokinetic

		Ratio	Quad BW Per	Ham BW Per	Peak Torque Quads	Avg Power Quads	Peak Torque Hams	Avg Power Hams	Delay Time
VJAVGm	r=	0.653	.742	0.788	0.681	0.663	0.716	0.704	-0.635
	p=	0.003	0	0	0.002	0.003	0.001	0.001	0.005
AVGSLJm	r=	0.662	0.712	0.757	0.657	0.646	0.686	0.69	-0.641
	p=	0.003	0.001	0	0.003	0.004	0.002	0.002	0.004

Table 2
Correlation of Vertical Jump and Standing Long Jump to 180°/sec isokinetic

		Ratio	Quad BW Per	Ham BW Per	Peak Torque Quads	Avg Power Quads	Peak Torque Hams	Avg Power Hams	Time to peak
VJ AVG (m)	r=	0.618	0.761	0.765	0.727	0.718	0.73	0.734	0.627
	p=	0.006	0	0	0.001	0.001	0.001	0.001	0.005
SLJ AVG (m)	r=	0.647	0.726	0.742	0.696	0.685	0.716	0.719	0.637
	p=	0.004	0.001	0	0.001	0.002	0.001	0.001	0.005

Stepwise linear regression took the factors from the correlations to determine the most important factors within the various comparisons. Hamstring % BW at 60°/sec (p=.000, r=.788, r^2=.621) were correlated with success in the VJ height. At 60°/sec, hamstring % BW (p=.000, r=.757, r^2=.573) were correlated with success in the SLJ distance. Hamstring % BW at 180°/sec (p=.000, r=.765, r^2=.585) were correlated with success in the VJ height. At 180°/sec, hamstring % BW (p=.000, r=.742, r^2=.551) were correlated with success in the SLJ distance. The predictors (p=.009, r=.920, r^2=.847) for peak power in the VJ were peak force, average velocity, athlete mass, and peak velocity. Stepwise linear regression indicated average velocity was the most important factor (p=;001, r=.825, r^2=.680). Important to success in VJ hieght when investigating power related factors was average velocity (p=.000, r=.840, r^2=.705, adjusted r^2=.678). The predictors (p=.029, r=.919, r^2=.845, adjusted r^2=.690) for average power in the SLJ were peak force, average velocity, athlete mass, and peak velocity. Stepwise linear regression indicated that average velocity (p=.000, r=.840, r^2=.705) was the most important component to SLJ distance.
Z-scores (See Figure 1) for the average power indicated that three athletes were +1 standard deviation away from the mean indicating higher power level generation during the VJ when compared to the SLJ. Three other athletes were -1 standard deviation away from the mean indicating higher power level generation during the SLJ when compared to the VJ. Peak z-scores indicated that three athletes were +1 standard deviation and two athlete was -1 standard deviation away from the mean.

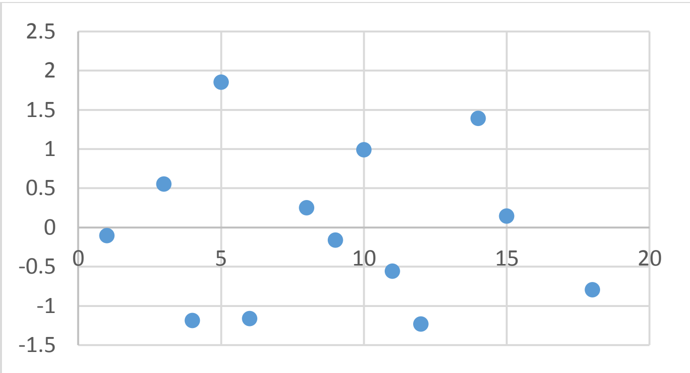

Figure 1: Distribution of the z-scores of the Average Power Ratio

DISCUSSION: The correlation of isokinetic variables to the VJ and the SLJ is expected. A surprise result was the lack of correlation between the power output variables and the performance tests. %BW of the hamstrings at both 60 and 180 being the most important factor in the VJ as well as the SLJ indicates the need for strength and power within the hamstrings to accomplish optimal VJ height and SLJ distance.
Visual comparison of the isokinetic testing and the VJ/SLJ ratio demonstrated an agreement with the z-scores. Only one athlete demonstrated appropriate H:Q ratio at both speeds. Seven

athletes demonstrated quadriceps dominant H:Q ratio at both speeds. Quadriceps dominance is an imbalance frequently occurring in female athletes (Myer et al., 2004). Two expressed hamstring dominant H:Q ratio at both speeds. A higher number of hamstring dominant athletes were expected. This is due deceleration skill needed by soccer athletes to kick and pass the ball (Cheung, Smith, & Wong del, 2012). The remaining athletes presented combinations of hamstring or quadriceps dominance at both speed and even within speeds. Mature girls have significantly greater quadriceps-to-hamstring ratio when compared with immature girls, immature boys, and mature boys (Ahmad et al., 2006).

The predictors for peak power in the VJ were peak force, average velocity, athlete mass, and peak velocity. These factors agree with known principles. The impact average velocity has on jump height success is also documented. Important to success in SLJ distance when investigating power related factors was average velocity. The predictors for average power in the SLJ were peak force, average velocity, athlete mass, and peak velocity. Again, this correlates with known physics principles.

Strength imbalance could affect an athlete's performance by limiting their ability to lower than optimal levels. An imbalance could also increase the risk of injury in an athlete. Using the performance tests of the VJ and the SLJ to determine the tendency in muscle dominance would allow sports medicine and strength staff to develop appropriate interventions tailored to the athlete to decrease the imbalance.

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