ANALYZING VERTICAL JUMP AND STANDING LONG JUMP POWER RATIOS TO DETERMINE LOWER EXTREMITY INJURY RISK USING AUROC CURVES

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This study examined ability to predict previous knee and thigh injuries in athletes by assessing allometrically scaled ratios of average power and peak power results from VJ (vertical jump) and SLJ (standing long jump) testing using ROC curves. Strength and conditioning testing data and medical records of 26 female NCAA-I from soccer and volleyball teams were examined. Data included isokinetic knee flexion and extension, VJ power, and SLJ power outputs. Previous injury was compared to scaled average power ratio, peak power ratio, and calculated z-scores for average power ratio and peak power ratio. The use of AUROC to assess power output ratios from performance testing to determine injury risk poorly predicted the possibility of a previous knee or a thigh injury.

KEYWORDS: muscle imbalance, isokinetics, injury risk, prediction

INTRODUCTION: Muscular strength imbalance is a factor placing athletes at risk for injury. The knee is vulnerable to injury when muscle imbalance is present. An imbalance between the hamstrings and quadriceps limits the ability of the hamstrings to act as an antagonist to control movement and stabilize the knee (Ahmad et al., 2006). Hamstring-quadriceps imbalance increases the risk of injuries such as muscle strains or ligament sprains (Ahmad et al., 2006; Zebis, Andersen, Ellingsgaard, & Aagaard, 2011). Hamstrings functioning at an optimal level create an appropriate hamstring-to-quadriceps ratio, knee flexion rate of force development, and hamstring muscle activation level to protect the ACL (Opar & Serpell, 2014). Male athletes activate the hamstrings sooner and more often than female athletes, have a higher hamstring-to-quadriceps ratio; these differences may contribute to females ACL injury rates (Opar & Serpell, 2014; Zebis et al., 2011). Female hamstring muscle activation also tends to be lower than that of males (Ahmad et al., 2006; Opar & Serpell, 2014; Zebis et al., 2011). A decreased rate of force development during initial movement in athletes may lead to decreased knee stability (Zebis et al., 2011). Impaired hamstring protection of the ACL during initial voluntary muscle contraction decreases the hamstring-to-quadriceps ratio, thus, decreasing knee joint stability (Zebis et al., 2011). Females exhibit greater levels of muscular imbalance between the hamstrings and quadriceps putting them at risk for ACL injury (Ahmad et al., 2006; Opar & Serpell, 2014). Female athletes take longer to develop muscle torque and frequently develop quadriceps dominance; which is an imbalance in the recruitment patterns between the quadriceps and hamstrings (Ahmad et al., 2006; Huston & Wojtys, 1996). Significant lower levels of muscular strength and endurance are present in female athletes (Huston & Wojtys, 1996). Weaker muscles fatigue more quickly resulting in greater imbalances and increasing injury risk (O'Sullivan, O'Ceallaigh, O'Connell, & Shafat, 2008). Female athletes tear ACLs at a higher than males. Women's soccer and women's volleyball suffered ACL injuries at a rate of 53.2% and 8.8%, respectively, between 2007-2012 (Joseph, et al., 2013).

Movement tests, such as the VJ (vertical jump) and SLJ (standing long jump), are used to determine power, athlete development, and quantify training protocol effectiveness. VJ height and SLJ distance results are valid measures of power (Kons, Ache-Dias, Detanico, Barth, Dal Pupo, 2018; Robertson & Fleming, 1987). Adding the power output to the VJ and SLJ, and an indication of leg power develops (Robertson & Fleming, 1987). Power outputs from a VJ and SLJ may provide a generic picture of an athlete's lower extremity injury risk (Konz, 2015; Mann, 2014). The power outputs from VJ and SLJ, when placed in a ratio, should be in agreement (Mann, 2014). For example, an individual with higher power output for the VJ compared with SLJ, is at risk of hamstring and knee injury (Mann, 2014).

The ability to use simple to apply and cost-efficient common movement tests, such as the VJ and SLJ, could greatly enhance the capabilities of allied health care professionals in determining at-risk athletes, as well as, to create protocols to minimize injury risk. The purpose of this study examined the ability to predict previous knee and thigh injuries in athletes by assessing allometrically scaled ratios of average power and peak power from VJ and SLJ testing using ROC curves. ROC curves of the average power VJ/SLJ ratio and the peak power VJ/SLJ ratio are not able to predict previous knee or thigh injury serves as the hypotheses for the study.

METHODS: Participants included a convenience sample of 26 female NCAA-I athletes from soccer and volleyball teams at one institution. The study examined strength and conditioning testing data from the athletes conducted before an off-season training cycle. All measurements were allometrically scaled (Markovic & Jaric, 2004). Athlete injury history was accessed to determine previous knee, quad, and hamstring injuries. The injuries were coded and used to assess sensitivity and specificity of allometrically scaled VJ and SLJ power outputs (Konz, 2015). Medical records along with strength and conditioning testing records of 13 female NCAA-I soccer and 13 female volleyball athletes were examined. The university IRB committee approved the study.
Testing results accessed included: Vertical jump (VJ) height, standing long jump (SLJ) distance, peak vertical jump power (PVJP), average vertical jump power (AVJP), peak vertical jump force (PVJF), peak standing long jump power (PSLJP), average standing long jump power (ASLJP), and peak standing long jump force (PSLJF), comprised the information taken from the strength and conditioning data (Konz, 2015). Power and velocity for the VJ and SLJ were determined using a TENDO Power and Speed Analyzer (TendoSport, Trencin, Slovak Republic). PVJP, AVJP, PSLJP, and ASLJP for the VJ and the SLJ tests were combined to form a power ratio (Konz, 2015). Average power for VJ and SLJ and peak power for VJ and SLJ formed the ratios. A comparison of these numbers allows for a dynamic means to determining hamstring or quadriceps dominance in athletes (Mann, 2014). 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 two power ratios were then converted to z-scores for analysis from the mean (Konz, 2015; Mann, 2014). Correlation and Receiver Operator Characteristics Area Under the Curve (AUROC) analyzed the relationships between previous injury and allometrically scaled power output variables. ROC curves evaluate the sensitivity and specificity of a test to determine a condition. Data were assessed for each team as well as the combined teams. Significance was set at the .01 level for the correlation analysis.

RESULTS: Volleyball athletes displayed higher VJ height, greater SLJ jump distance, and greater power outputs (Table 1). AUROC analysis of the separate team analysis determined fair to fail prediction values for volleyball injuries. Average VJ power (0.767) assessed the previous injury at a fair rate. AUROC analysis of the separate team analysis determined good to fail prediction values for previous injuries in soccer. The ratio of VJ/SLJ peak power (0.833) resulted in a good predictor for previous injury in soccer. Average VJ power (0.767) assessed the previous injury at a fair rate. AUROC curves for the combined team variables indicated the area under the curve was as follows average VJ power (0.631), peak VJ power (0.663), average SLJ power (0.622), and the VJ/SLJ peak power ratio (0.663).

Table 1: Mean and Std. Deviations for Variables of Note

	VJ (cm)	VJ-Avg. Power (W)	VJ-Peak Power (W)	SLJ (m)	SLJ-Avg. Power (W)	SLJ-Peak Power (W)
VB (n=13)	1.27 (±0.18)	1136.2 (±208.9)	5491.8 (±1640.6)	2.01 (±0.19)	686.3 (±183.3)	5293.1 (±1854.7)
Soccer (n=13)	1.04 (±0.13)	918.9 (±189.3)	4456.1 (±1149.8)	1.92 (±0.14)	566.8 (±162.5)	6447.0 (±1167.3)

Combined (n=26)	1.14 (±0.20)	1027.0 (±224.3)	4973.9 (±1485.1)	1.9 (±0.2)	626.6 (±180.4)	5870.0 (±1628.3)

The results of the ROC curve analysis poorly indicated previous knee or thigh injury in the teams. ROC curves indicate that the ratio of average power output for VJ and SLJ (0.406) does not predict a previous injury while the peak power output for VJ and SLJ (0.663) poorly predict injury history (Figure 1).

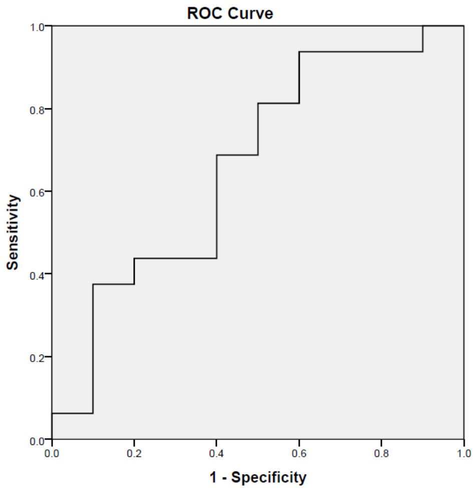

Figure 1. AUROC Curve of VJ and SLJ Peak Power comparison

DISCUSSION: The purpose of this study was to examine the ability to predict previous knee and thigh injuries of athletes using ROC curves to assess allometrically scaled ratios of average power and peak power from VJ and SLJ testing. The original premise driving the VJ versus SLJ comparison outlines the use of z-scores to determine injury risk in athletes (Mann, 2014). Z-scores determine how far a score is away from the mean of the population. No ability to predict injury risk exists when using z-scores of the VJ/SLJ ratios. AUROC curves are tailored to predict or classify a condition and the accuracy of the predictor is measured by the area under the curve (Portney & Watkins, 2009). The z-scores for average power ratios and peak power ratios failed in their sensitivity and specificity to predict previous injury. The results of the AUROC curve analysis poorly indicated previous knee or thigh injury in the teams with a sensitivity and specificity for VJ average power (0.631), VJ peak power (0.663), SLJ average power (0.622), and VJ/SLJ peak power ratio (0.663) in predicting previous injury. AUROC curves indicated the ratio of average power output for VJ and SLJ (0.406) failed to predict previous injury while peak power output for VJ and SLJ (0.663) poorly predicted injury history.

Mann (2014) indicated that athletes with a great VJ height combined with a poor SLJ distance might be at a greater risk of hamstring or knee injury. A reason for the lack of prediction may be the complicated nature of the VJ and SLJ vertical and horizontal components (Shons, et al.,2018; Robertson & Fleming, 1987). The need for horizontal velocity and force is not as important in VJ height as the relationship between the horizontal and vertical velocity and force during the SLJ (McErlain-Naylor, King, & Pain, 2014; Robertson & Fleming, 1987). Joint kinetics are an important aspect of VJ (McErlain-Naylor, King, & Pain, 2014) and SLJ. The muscle contraction sequence for the VJ is different from the SLJ even though three extensor moments produce leg extension after take-off in a simultaneous fashion (Robertson & Fleming, 1987). Knee musculature contributes less to force production than the ankle and hip muscles during a VJ or SLJ (Robertson & Fleming, 1987). Mann (2014) detailed the VJ is more hip extension and plantar flexion dominant. Robertson & Fleming (1987) determined the VJ is a simultaneous activity with the hip (40.0%) contributing the majority of the force production followed by the ankle (35.8%). McErlain-Naylor, et al. (2014) contrast the previous results with the knee being the prime force producer followed by the ankle and hip, respectively. Also, research indicates the ankle moves towards plantar flexion, but is not always plantar flexed (Robertson & Fleming, 1987). Mann (2014) further detailed the SLJ is more knee extension and dorsiflexion dominant. Ankle movement during the SLJ is dorsiflexion moving toward plantar flexion with the ankle (50.2%) contributing the majority of the force production followed by the hip (45.9 %) but not the knee (3.9%) (Robertson & Fleming, 1987) which is contrary to the SLJ being knee extension dominant. During maximal force production, peak ankle power is influenced by greater ankle plantar-flexion during the VJ (McErlain-Naylor et al., 2014). Ankle mobility issues due to a previous injury can confound the results of the present testing approach (Mann, 2014).

CONCLUSIONS: Using AUROC curves to predict previous knee or thigh injury using VJ/SLJ power ratios poorly predicts the possibility of a previous knee or a thigh injury. Previous ankle injury or compromised mobility can impact the ability to get meaningful information from the VJ/SLJ ratio (Mann, 2014). An athlete without a history of ankle related issue is hard to come by in soccer or volleyball. But, are we investigating the right joint given the two-joint muscles of the leg? Also, would training athletes to be more symmetrical decrease sport-specific skills?

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