DEVELOPMENT OF A NEW ASSESSMENT METHOD FOR THE REBOUND JUMP TEST

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We have proposed a new assessment method using joint kinetics and performance variables in the rebound jump (RJ) test. Twenty-seven male jumpers performed the RJ test. The Quick Motion Analysis System (jointly developed with DKH Inc.) was used to measure joint torque, power, and work of the three lower limb joints in real time, with high precision. High-performance jumpers had high performance values and showed a significantly large amount of joint work in the ankle and hip joints on the RJ test. Comparison of the work of the three lower limb joints confirmed a conflicting relationship between the hip and knee joints and that of the ankles, indicating that this new system is useful for evaluating joint kinetics of the three lower limb joints and may contribute greatly to the assessment of muscle strength and power.

KEYWORDS: stretch-shortening cycle movement, performance variables, joint kinetics.

INTRODUCTION: In sprint running and jumping track-and-field events, as well as ball sports, the agonist muscles in the lower limbs are subjected to stretch-shortening cycle (SSC) movements, with extremely short contact times of ≤0.2 seconds, that exert a ground reaction force approximately 10 times the individual's body weight. Thus, it is necessary to measure the SSC performance of athletes. Drop jump and rebound jump tests are generally used to test SSC performance (Bobbert, 1990 ; Young, 1995 ; Yoon, 2007), although performance variables such as contact time, jumping height, and rebound jump index (RJ-index ; Zushi et al., 1993; Tauchi et al., 2008) have also been used. These performance variables result from interactions between muscle groups and three joints in the lower limbs. Therefore, if a new measurement system is developed that can measure and calculate the mechanical variables of the three lower limb joints (torque, power, and work) in real time with the performance variables, athletes' SSC performance can be diagnosed in more detail and with greater accuracy. Therefore, effective training practices can be promoted and athletic performance can be improved. Therefore, in this study, a new system that can measure mechanical variables of the three lower limb joints in real time was developed and a new evaluation/diagnostic method that uses performance and mechanical variables was proposed.

METHODS: Twenty-seven male track and field jumpers (age, 20.7 ± 1.7 years; height, 176.52 ± 5.59 cm; mass, 67.85 ± 5.06 kg; International Association of Athletics Federations [IAAF] score, 990.3 ± 86.6) participated in this study. Here, IAAF score refers to the jump events performance used by the IAAF Scoring Tables of Athletics. Informed written consent was obtained from each participant. After a warm-up, the subjects performed a rebound jump (RJ) at least three times. The RJ was repeated in a vertical direction by using both legs in a standing posture. The subjects were orally instructed to shorten the ground contact time as much as possible and jump as high as possible. The three-dimensional coordinates of 12 retroreflective markers fixed on each subject's body were collected by using a Vicon T20 system (Vicon Motion System, Ltd.) with 10 cameras operating at 250 Hz. The ground reaction force was obtained with the force platform at 1000 Hz.

The RJ index, which indicates the mechanical power per body mass during take-off (Zushi et al., 1993; Tauchi et al., 2008), was calculated by dividing the jump height by the contact time. The trial with the highest RJ index was selected for further analysis. The joint torque, torque power, and joint work (done by joint torque) of the lower leg (take-off leg side) were calculated by using inverse dynamics. Relative work was calculated as the ratio of work for each joint relative to the total sum of work for the three lower limb joints. Previously, significant time and labor were required to calculate joint kinetics; however, in this study, the Quick Motion Analysis System, which automatically calculates and presents the above-mentioned data immediately after RJ practice, was jointly developed with the DKH Inc. in Japan and used in the measurements Relationships between variables were determined by using the Pearson correlation test. One-way analysis of variance and Tukey post hoc test were used to determine the differences between variables. Statistical significance was set at P < 0.05.

RESULTS & DISCUSSION: There are four jumping events (high jump, long jump, triple jump, and pole vault), but since the records for all events could not be presented on a single graph, the data were converted to IAAF scores. The correlations between IAAF score and the RJ performance variables were examined (Figure 1). The results showed that the correlation coefficient between IAAF scores and RJ index had a significant positive correlation(r = 0.441, P < 0.05), while a significantly positive correlation was noted with jumping height (r = 0.523, P < 0.05). Thus, our findings indicate that jumpers' specialized muscle strength and power exertions can be evaluated by jumping height and RJ index.

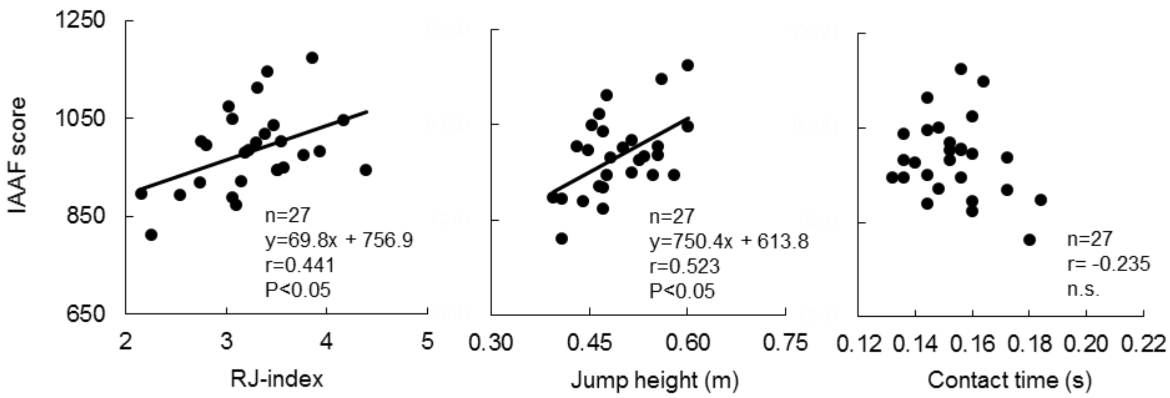

Figure 1: Relationship between the jumpers' International Association of Athletics Federations (IAAF) scores and performance variables on the rebound jump (RJ) test. n.s., not significant.

We examined the correlation between IAAF score and mechanical variables of the three lower limb joints (Figure 2). The top three Japanese athletes with competition experience at international events (×, HJ 1: IAAF score, 1175; △, HJ2: IAAF score, 1147; ◇, LJ1: IAAF score, 1113) are shown. HJ1 (×) was a world-level high jumper who placed high in the 2014 Diamond League Monaco and Brussels competitions. Significant correlation coefficients were noted between IAAF score and negative ankle work (r = −0.445, P < 0.05), and absolute work of ankles (r = 0.423, P < 0.05); and between IAAF score and positive hip joint work (r = 0.574, P < 0.01) and absolute hip joint work (r = 0.467, P < 0.05).

These results indicate that for higher-performing athletes, the ankles perform a large amount of work to receive the impact of the RJ landing. Toward the end of the toe off, the hip joint does a large amount of work that contributes to the high jumping height. However, no characteristics were associated with the knee joints. Furthermore, significant correlation coefficients were found between IAAF score and variables associated with the ankle and the hip joint for joint torque, joint power, and relative work; however, no notable characteristics were associated with the knee joints. Therefore, high-performance jumpers were characterized by a significantly large amount of work in the ankle and hip joints on the RJ test.

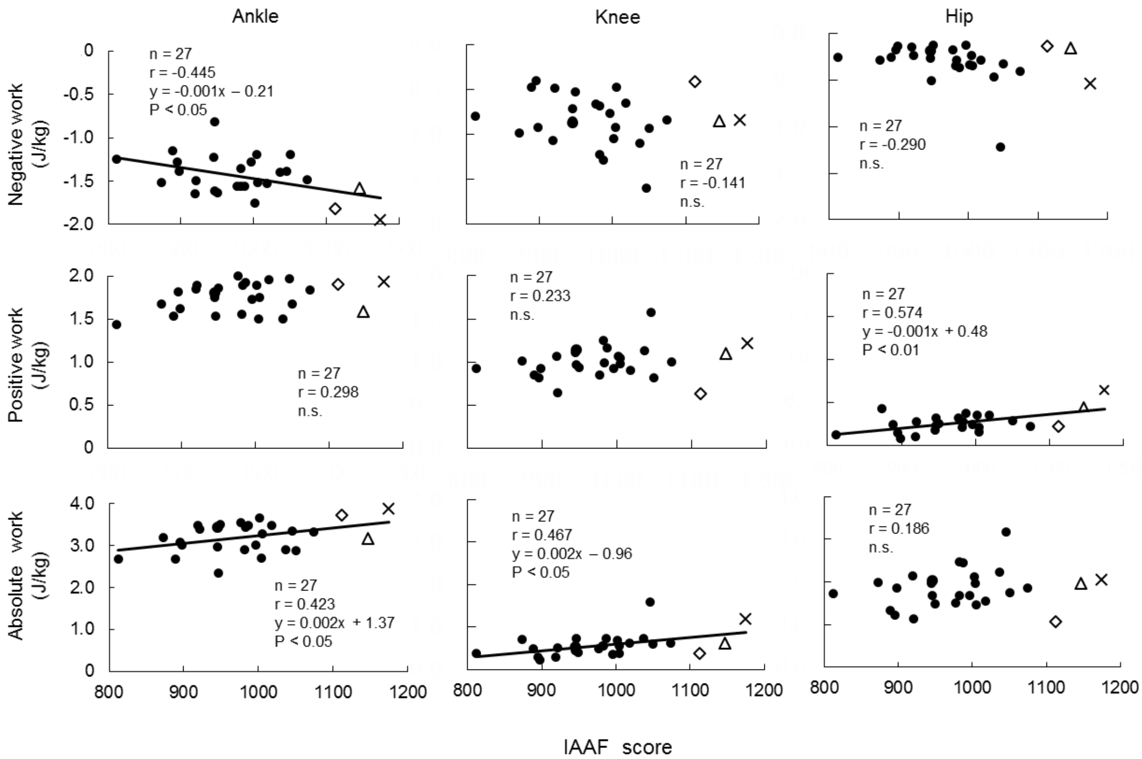

Figure 2: Relationship between the International Association Athletics Federations (IAAF) score and work by the three lower limb joints. n.s., not significant.

Next, we examined the correlations between the functions of the three lower limb joints (Table 1). Table 1 shows the correlation coefficients between the ankle, knee, and hip joints in terms of torque, power, work, and relative work. No significant correlation coefficients were noted between the ankle and knee joints in terms of torque, power, or work. However, a significant positive correlation coefficient was noted for power between the ankle and hip joints (negative maximum power: r = 0.584, P < 0.01; positive maximum power: r = 0.414, P < 0.05; negative mean power: r = 0.398, P < 0.05). Between the knee and hip joints, significant positive correlations were found for torque (maximum torque: r = 0.593, P < 0.01; concentric phase mean torque: r = 0.634, P < 0.01), power (negative mean power: r = 0.744, P < 0.01), and work (negative work: r = 0.597, P < 0.01; absolute work: r = 0.634, P < 0.01).

Furthermore, for relative work, significant negative correlation coefficients were found in the ankle and knee joints (negative relative work: r = − 0.817, P < 0.05; positive relative work: r = −0.788, P < 0.01, total relative work: r = −0.862, P < 0.01) and in the ankle and hip joints (negative relative work: r = −0.703, P < 0.01; positive relative work: r = −0.430, P < 0.05; total relative work: r = −0.622, P < 0.01).

These results showed that there is a relationship in work between the three lower limb joints and that work by the hip, knee, and ankle joints are in a conflicting relationship. Work by the hip and knee joints, which are positioned at the center of the body and associated with a large muscle group, and that of the ankles, which are positioned at the end of the body and have a large proportion of tendons, are in a conflicting relationship. It can be assumed that there is a mechanism that stipulates that when work by any joint increases, the functions of others are suppressed. This mechanism may be explained by the functional, anatomical, and mechanical properties of each joint. These factors should be examined in detail in a future study.

Table 1 Correlations between ankle, knee, and hip joints and the mechanical variables

		Ankle・Knee	Ankle・Hip	Knee・Hip
Joint torque (Nm/kg)	Maximum	0.173	0.306	0.593 **
	Eccentric	0.210	0.265	0.333
	Concentric	0.034	-0.031	0.446 *
Joint power (W/kg)	Negative max	0.128	0.584 **	0.363
	Positive max	-0.003	0.414 *	0.303
	Negative mean	0.313	0.398 *	0.744 **
	Positive mean	-0.137	0.347	0.351
Joint work (J/kg)	Negative	-0.001	-0.102	0.597 **
	Positive	0.015	0.385	0.348
	Absolute	0.006	0.221	0.634 **
Relative joint work (%)	Negative	-0.817 **	-0.703 **	0.164
	Positive	-0.788 **	-0.430 *	-0.218
	Absolute	-0.862 **	-0.622 **	0.139

**P < 0.01; *P < 0.05

CONCLUSION: In this study, a new system was developed to measure the mechanical variables of the three lower limb joints in real time. An evaluation/diagnostic method based on variables of the three lower limb joints (torque, power, and work) was examined to present the following points:

(1) High-performance jumpers had high performance variable values on the RJ test (RJ index and jumping height) and were characterized by high SSC performances in the lower limbs.

(2) High-performance jumpers were characterized by a significantly large amount of work in the ankle and hip joints on the RJ test.

(3) There is a relationship in work among the three lower limb joints, while work by the hip and knee joints had a conflicting relationship with work by the ankles.

(4) By using the new system (developed for this study to measure the mechanical variables of the three lower limb joints in real time), we evaluated torque, power, work, and relative work. This system may be quite useful for assessing muscle strength and power.

In the future, the RJ test will be conducted by using this new system with a focus on various competitive events, competition levels, and sex differences. Accordingly, large amounts of data on mechanical variables of the three lower limb joints will be accumulated, standard values will be determined for training and discovering new athletic talent, and more efficient assessment methods will be developed.

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