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ORIGINAL SCIENTIFIC PAPER

The Relationship between Jump Ability and Athletic Performance in Athletic Throwers

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Abstract

The purpose of this study was to examine the relationship between jump ability and athletic performance of athletic throwers based on data taken over two years. The data of 24 1st-year and 2nd-year male university throwers was compiled to examine the relationship regarding athletic performance. In summary, the three events of standing long jump (SLJ), squat jump (SJ), and counter-movement jump (CMJ) were always in a positive correlation with athletic performance in the two-year measurement. Next, SJ was most relevant to the athletic performance of the five jump measurement items. Standing triple jump (STJ) and rebound jump (RJ) did not improve in two years, and no association with the athletic performance was seen. These results suggest that simple explosive exercises, such as SLJ, SJ, and CMJ, are effective for evaluating the physical fitness of throwers. The vertical jump capability is particularly useful for evaluating athletic performance. The innovation of this study is found in SJ, which exerts power from a stationary state, and could be significant in optimizing athletic performance, which can be enhanced through modified training practices that incorporate SJ.

Keywords: *Throwers, Jump ability, performance, male, vertical jump*

Introduction

There is much evidence of the relationship between athletic performance and jump ability in athletic throwers (Takanashi, Aoki, Komura, Yonamoto, & Kaneko, 2009; Hatakeyama, Takanashi, & Sasaki, 2011; Maeda, Ohyama, Hirose, & Ogata, 2018; Aoki, Yoshimitsu, Kazuhiko, Kazunori, & Hisashi, 2015; Victor & Artur, 2003; Zaras, Stasinaki, Arnaoutis, & Terzis, 2016). Two types of measurement events, horizontal and vertical, are used to measure jump abilities. Horizontal jumping events often use standing long jumps and standing triple jumps, which are known to have a positive correlation with athletic performance (Takanashi et al., 2009; Hatakeyama et al., 2011; Maeda et al., 2018). In contrast, vertical jump types include a jump without a counter-movement (squat jump) and a jump using a counter movement (counter-movement jump). In addition, the event at which a person bounces off the ground multiple times is referred to as a rebound jump. Jump events to the vertical also have reported a positive correlation with athletic performance (Tauchi, Yoon, Kuriyama, & Takamatsu, 2002). Despite a good example of the vertical jump data shown of the world's top athlete in the shot put (Babbitt & Hoffa, 2019), there are few reports of vertical jumps overall, which may be attributed to the need of a specific device, such as a force plate or a matte switch.

There is a positive correlation between physical fitness and athletic performance, which require instantaneous power for movements such as jump ability. This is easy to predict, as the throwing distance is almost entirely determined Juby the velocity at the time of release (Gregor, Whiting, & McCoy, 1985; Dapena, 1984; Hunter & Kiggore, 2003; Murakami et al., 2006). However, the evidence for the relationship between jump ability and athletic performance simply examines the relationship between temporary physical fitness and performance. Few examples mention the change of the performance with the longitudinal change of the jump ability, other than the report by Babbit and Hoffa (2019), which shows an example of a longitudinal report of the physical strength and performance

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of one of the world's top shot putters. It is essential to ensure that the improvement of jump ability also improves athletic performance. It helps to assess the appropriateness of training in practice and to plan training.

In addition, various events, such as horizontal jumping, vertical jumping, and the presence or absence of counter-movement, have been used to study the relationship between jump ability and performance. Some of these jump ability measurement events have been treated as one jump ability without distinction. However, the physical strength reflected by the characteristics of the measurement event should be different. To date, there is no evidence to measure multiple jump ability. Therefore, this study measured the jump ability of male athletic throwers by multiple measurement severity and examined the relationship between athletic performances.

Methods

Subjects

This study aimed to measure the jump ability of 24 male university student-athletic throwers, the data for which was to be collected over the course of two years. The group consists of 2 shot putters, 10 discus throwers, 7 hammer throwers, and 5 javelin throwers. The athletic performance was scored at the Scoring Table of the International Association of Athletics Federations (IAAF). Characteristics of the subjects are as shown in Table 1.

Table 1. Characteristics of Subjects (1st year)

variable	Mean±Standard Deviation
Age	18.4±0.7
Body Height (cm)	177.17±5.28
Body Mass (kg)	88.60±9.70
IAAF Score	753.96±57.64

Legend: IAAF Score - Athletic performance scored at the Scoring Table of the International Association of Athletics Federations

This study was approved by the ethics committee of the Juntendo University School of Health and Sports Science (No.31-91). Potential candidates were given a verbal or written explanation of the study objectives, and those who gave written, informed consent to participate were enrolled. The data was anonymized in advance to third parties who were not related to this study. Therefore, the research was carried out in situations in which it was impossible to identify individuals.

Measurement data

The data in this study were two measurements of the subject's 1st and 2nd year between 2010-2018 was used. All measurements were controlled by the same supervisor.

Standing Long Jump

The operating image of the standing long jump (SLJ) is shown in Figure 1 (a). The legs were set to shoulder width, and the jump was made by using the recoil of the arms and the legs. The subjects were instructed to try to jump as far as possible.

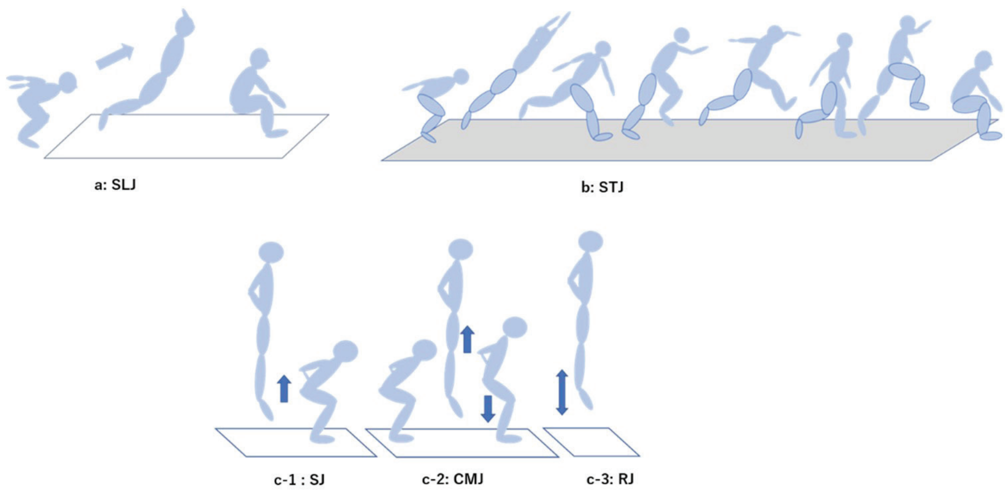

FIGURE 1. The illustration of the method of the jump test - Standing long jump (SLJ), Standing triple jump (STJ), Squat jump (SJ), Counter-movement jump (CMJ), Rebound jump (RJ)

Standing Triple Jump

The image of the standing triple jump (STJ) is shown in Figure 1 (b). The legs were set to shoulder width, and the recoil of the arms and legs were used to make the jump in three strides. The subjects were instructed to make an effort to land as far as possible.

Squat Jump

The squat jump (SJ) was measured using a mat switch (DKH multi-jump tester, Tokyo, Japan). The mat switch is activated by pressure. The measurement image is shown in Figure 1 (c-1). The angle of the knee joint was set at 90 degrees, and the jump was made without using recoil. The jump height was calculated from the time it took to land from the departure at the time of jumping.

Counter Movement Jump

The counter-movement jump (CMJ) was measured using a mat switch. The measurement image is shown in Figure 1 (c-2). The subjects held their hands on their hips and leapt using recoil. The jump height was calculated from the time it took to land from the departure at the time of jumping.

Rebound Jump Index

The rebound jump index (RJ-Index) was measured using a mat switch. Five consecutive jumps were carried out on the mat. The subjects were instructed to jump as high as possible and keep the contact time short between the jumps (Figure 1, c-3). Of the five jumps, the highest value was adopted as the measured value. This index is a figure that excludes the jumping height by the installation time.

Data Analysis

A comparison of the measurements of 1st and 2nd-year students and the difference in the rate of change were made using repeated measured t-test. The collected data were investigated using Pearson's accumulation correlation coefficient to investigate the association with the athletic performance for each year. The significance level was set at less than 5%.

Results

Athletic Performance

The results are shown in Table 2, in which the mean score of the subjects in this study was 753.96±57.64 points, which is the advanced level that can compete in national competitions in Japan. The mean IAAF Score at the time of the 1st year was 753.96±57.64, which advanced to an average score of 814.50±50.27 at the time of the 2nd year. There was a significant difference in the value of this pair (p<0.001). In other words, the score of all 24 athletes improved.

Table 2. Results of all measurement types

	1st year Mean±SD	2nd year Mean±SD	1st vs 2nd	% Change	Correlation between IAAF Score of % Change
IAAF Score	753.96±57.64	814.50±50.27	***	108.23±4.47***	
SLJ (m)	2.72±0.17	2.79±0.16	**	102.59±3.51**	0.305
STJ (m)	7.90±0.62	7.96±0.61		100.88±2.61	-0.064
SJ (cm)	39.47±5.30	40.93±4.89	**	104.01±5.43**	0.437**
CMJ (cm)	46.42±7.06	47.92±7.42	**	103.30±4.44**	0.221
RJ Index	2.08±0.35	1.98±0.40		95.26±12.93	0.142

Legend: * - p<0.05; ** - p<0.01; *** - p<0.001; 1st vs 2nd - paired t-test at 1st year and 2nd year; %Change - Change of 100% between 1st and 2nd year; SLJ - Standing long jump; STJ - Standing triple jump; SJ - Squat jump; CMJ - Counter-movement jump; RJ Index - Rebound jump index

Standing long jump (SLJ)

The results are shown in Table 2 Standing long jump was 2.72±0.17 m at the time of the 1st year, 2.79±0.16m at the time of the 2nd year. There was a significant difference in the value of this pair (p<0.01). The association with athletic performance was r=0.411 (Table 3) at the time of the 1st year (p<0.05), r =0.408 (Table 4) at the time of the 2nd year (p<0.05).

Standing triple jump (STJ)

The results are shown in Table 2. The record was 7.90±0.62m at the time of the 1st year, 7.96±0.61 m at the time of the 2nd year for standing triple jump. Furthermore, the association with athletic performance was r=0.245 (Table 3; ns) at the time of the 1st year, r=0.373 (Table 4; ns) at the time of the 2nd year.

Squat jump (SJ)

The values at the time of the 1st year were 39.47±5.30 cm, 40.93±4.89 cm at the time of the 2nd year for Squat jump. There was a significant difference in the value of this pair (p<0.01). The association with athletic performance was r=0.528 (Table 3; p<0.01) at the time of the 1st year, r=0.582 (Table 4) at the time of the 2nd year (p<0.01) (Figure 2).

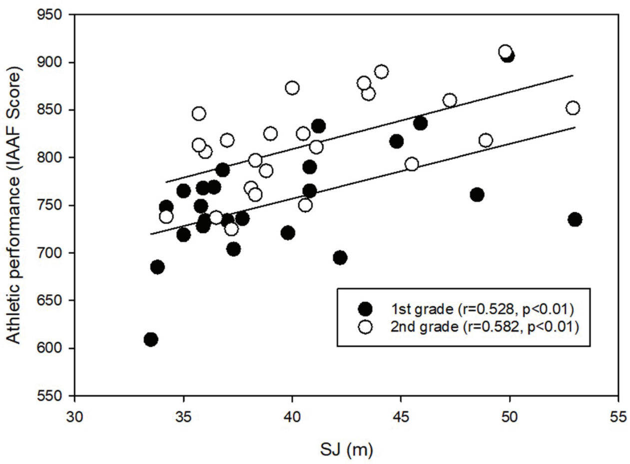

FIGURE 2. The Correlation between Athletic performance and Squat jump (SJ: Squat jump)

Counter movement jump (CMJ)

The values for Counter movement jump were 46.42±7.06 cm at the time of the 1st year, 47.92±7.42 cm at the time of the 2nd year. There was a significant difference in the value of this pair (p<0.01). The association with athletics performance was r=0.538 (Table 3) at the time of the 1st year (p<0.01), r =0.511 (Table 4) at the time of the 2nd year (p<0.05).

RJ-Index

The RJ-Index showed values at 2.08±0.35 at the time of the 1st year, 1.98±0.40 at the time of the 2nd year. There was a relationship between the athletic performance of r=0.319 (Table 3; ns) at the time of the 1st year, r=0.403 (Table 4; ns) at the time of the 2nd year.

Between-measurement items

The relationship between the measurements of each grade and athletic performance is shown in Tables 3 and 4.

The three SLJ, SJ, and CMJ events had a significant positive correlation with each other in two-year measurements.

Table 3. Relationship between measurement types in the 1st year

	SLJ	STJ	SJ	CMJ	RJ
IAAF Score	0.411*	0.245	0.528**	0.538**	0.319
SLJ		0.374	0.759***	0.831***	0.560**-
STJ			0.374	0.541**	0.369
SJ				0.867***	0.454*
CMJ					0.534**

Table 4. Relationship between measurement types in the 2nd year

	SLJ	STJ	SJ	CMJ	RJ
IAAF Score	0.408*	0.373	0.582**	0.511*	0.403
SLJ		0.274	0.683***	0.781***	0.326
STJ			0.513*	0.434*	0.222
SJ				0.849***	0.474*
CMJ					0.59**

The combination with the highest correlation coefficient was SJ and CMJ (the 1st year: r=0.867, the 2nd year: r=0.849). In contrast, RJ was significantly positively correlated between SJ and CMJ in two years. However, RJ and STJ showed no significant correlation in two years.

Correlation of rate of change

We investigated the correlation between the rate of change as a reference for verifying the relationship between athletic performance and measurement items. As a result, SLJ (r=0.305, ns), STJ (r=-0.064, ns), CMJ (r=0.221, ns), RJ (r=0.142, ns) was not significantly related to Athletic performance. In contrast, SJ showed a significant positive correlation with athletic performance (r= 0.437, p<0.01).

Discussion

The results of this study, showing a significant positive correlation between SLJ, SJ, and CMJ and athletic performance, are indeed consistent with previous reports establishing the relationship between jump ability and athletic performance (Takanashi et al., 2009; Hatakeyama et al., 2011; Maeda et al., 2018; Aoki et al., 2015; Victor & Artur, 2003; Zaras et al., 2016).

Prior to their training intervention, the subjects' performance level maintained a mediocre status that could nonetheless compete in the nationwide competition in Japan, but in one year it has improved to a high level to finish within 8th place in the same competition. For this reason, the measurement of jump ability reflects the athletic performance of the thrower from the middle class to the high class. Previous studies have evaluated the same explosive capabilities, both horizontally and vertically. However, the direction and type of jump are important issues that have not been thoroughly reported.

The best correlation between these jump events and athletic performance is seen in SJ at the 2nd year (r=0.582), followed by CMJ at the 1st year (r=0.538). In particular, SJ maintained a 1% level of relevance with athletic performance in both the 1st year and the 2nd year. All results were strongly correlated than any of the horizontal values. In other words, the jumping power of athletic throwers is best evaluated in the vertical plane. It is difficult to clarify why this is the case for only this study. However, historical evidence has reported that SLJ, which is a horizontal jump, has little intervention in the muscle group of the knee (Toriumi, Amano, & Terasawa, 1988). By analysing vertical jump ability, it is possible to evaluate the relevant jumping force of the knee muscle group. This is because that group is important for the thrower (Bourdin et al., 2010). In addition, it may be possible to predict from the operation of the throwing motion. For example, it has been reported that the distance of the shot put has a greater influence on the vertical force than the horizontal direction (Kaneko et al., 1998). This is believed to contribute to lifting the legs and transmitting ground reaction forces to the shot during the release phase of the movement. The results of this study also showed a significant positive correlation between the three jumps' measurements other than STJ and RJ, which had similar results for all measurements over the two years. This is to say that athletic performance also improved with jump ability, starting at 753.96±58.88 in the first grade and rising to 814.50±50.27 by the second year. In the field of practice, avoiding going too far in the projection direction is often advised. In other words, in order to benefit from ground reaction force, it is thought that it is important to exert force in the vertical downward direction, thus contributing to the significance of the results.

It is interesting that SJ was the most relevant event to athletic performance, given it is the only one of the five measurement stakes to require an explosive jump from the stationary state. SJ's best reflection of athletic performance suggests that it is an important factor for the thrower. As the vertical jumping events, SJ and CMJ, are highly correlated with athletic performance (the 1st year: r=0.867, the 2nd year: r=0.849), which may lead to improved instantaneous power, including technical elements, such as CMJ, by improving simple, instantaneous power like SJ. Furthermore, as shown in Table 2 in this study, the significant positive correlation between athletic performance and the rate of change in SJ ($r=0.437$, $p<0.01$) also increases the likelihood that SJ is important.

In contrast, there was no significant association between RJ and athletic performance in any of the two-year studies, in contrast to the results of a report by Tauchi et al. (2002). Of the five jump events in this study, RJ is the event at which the highest strength stretch shorting cycle (SSC) was required. RJ is a high-strength SSC, where the movement characteristics are different from the SLJ and STJ commonly used (Zushi, Takamatsu, & Kotoh, 1993). Therefore, RJ showed a different result than SJ or CMJ. There is evidence when the javelin thrower is better than the other throwers. While this study contained only five javelin throwers, it would be prudent to consider more athletes of the same event and more of different events in future studies.

Furthermore, RJ and STJ are similar in that they repeat the bounce. However, there was no significant correlation between the pair. STJ may differ from the fact that the first step does not use a high-strength SSC and that the magnitude of the stride affects it. While STJ continually rose in two years, despite lacking significance, RJ did not as it may be a special measurement item. In this study, it was not related to other jump events, and it was not possible to improve it by training as it originally measures the ability of the tendons inherent in the body. In addition, weight increase may stagnate the value of RJ, but this is expected. Nonetheless, RJ does not need to be excluded just because it is not valid for evaluation since it may be an important training exercise to maximize the strength of the athletes' tendons.

Given these results, it can be stated that not only the direction of the jumping force but also the motor characteristics influenced this result. SLJ is an explosive exercise, having the same as the motor characteristics as SJ and CMJ. In contrast, STJ and RJ, which did not have a significant positive correlation with athletic performance, are both continuous. They also have something in common to use SSC for tendons. They are not events that measure only the ability to exert simple power as they measure the technique, as well. For these reasons, a simple explosive jump event may be suitable for the physical fitness evaluation of the athlete at the level of transition from intermediate to advanced.

As mentioned earlier, this study examined five jump events, but all events have different characteristics. STJ requires techniques to link landings to the next jump and the movement of the centre of gravity. SJ requires an explosion from a stationary state. The CMJ requires vertical explosion using recoil action. RJ requires a high-strength SSC and had no significant association with athletic performance but may be necessary for training. On-site coaches and athletes should, therefore, understand and evaluate these characteristics.

These results suggest that simple explosive exercises such as SLJ, SJ, and CMJ are effective for evaluating the physical fitness of throwers. The vertical jump capability is particularly useful for evaluating athletic performance. The innovation of this study is found in SJ, which exerts power from a stationary state, and could be important in optimizing athletic performance, which can be enhanced through modified training practices that incorporate SJ. In contrast, STJ and RJ, which do not have a significant association with athletic performance, may not be reliable as a physical fitness assessment event, but we consider them important for training, nonetheless.

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Conflict of Interest
The authors declare the absence of conflict of interest.

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