Original Article

Relationship between competitive and jumping abilities in university track and field athletes

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Abstract

Introduction: There are various criteria for fitness tests performed to evaluate the effect of training. A strong relationship has been reported between sprinting and jumping abilities in track and field. Jumping ability has been utilized as a field test in both vertical and horizontal directions. In addition to studying vertical jumping ability, which has been reported in previous studies, we studied the relationship with horizontal jumping ability (measurement variable), which can be easily performed during coaching to identify the correlation between effective jumping and competitive abilities in track and field. **Materials and Methods:** We analysed 137 male university athletes specializing in track and field. We measured their jumping ability in vertical and horizontal directions. Their competitive records were converted into a score using the International Association of Athletics Federations (IAAF) scoring tables. **Results:** The highest correlations were for standing 10-stride jump for short distance, vertical jump (VJ) for middle-distance, countermovement jump (CMJ) for hurdles, standing quintuple jump for jumping, and standing triple jump for throwing. CMJ, rebound jump (RJ)-index, standing quintuple jump, and standing 10-stride jump were the highest for all events, overall. **Conclusions:** CMJ, RJ-index, standing quintuple jump, and standing 10-stride jump are effective common indicators that have high correlations with competitive ability for track and field athletes in short-distance, middle-distance, hurdling, jumping, and throwing events. Furthermore, because the correlation between standing quintuple and 10-stride jumps and CMJ and RJ-index is high, these may be considered effective measurement variables that anybody can easily measure in the context of training approaches.

Keywords: Horizontal Jumping, Vertical Jumping, IAAF Scoring Table, Jumping Ability, Athletes

Introduction

There are various criteria for fitness tests performed to evaluate the effect of training, develop new training methods, assess conditioning, and predict performance in a number of sports, including track and field, tennis, handball, and swimming (Bencke et al., 2002; Chelly & Denis, 2001; Girard, Chevalier, Leveque, Micallef, & Millet, 2006; Kyriazis, Terzis, Karampatsos, Kavouras, & Georgiadis, 2010).

In terms of fitness tests for track and field, sprinting and jumping abilities are reportedly strongly correlated (Aoki, Kohmura, Sakuma, Koshikawa, & Naito, 2015). Specifically, the relationship between sprinting and vertical jumping abilities has been studied in a variety of subjects, and the association with countermovement jump (CMJ) height has been shown to be high (Köklü, Alemdaroğlu, Özkan, Koz, & Ersöz, 2015; Markström, & Olsson, 2013; Nagahara, Naito, Miyashiro, Morin, & Zushi, 2014). Furthermore, although there are few studies on this subject, there have been reports of a relationship between sprinting ability and horizontal jumps such as the standing long jump and standing triple jump (Brechue, Mayhew, & Piper, 2010; Hudgins, Scharfenberg, Triplett, & McBride, 2013; Misjuk & Viru, 2007). Therefore, jumping ability is especially important for sprinting among track and field events.

Track and field can be broadly divided into running, jumping, and throwing categories and more finely divided into 22 events. Unlike previous studies that have reported only a relationship with jumping ability in short-distance athletes, in this study, we evaluated competitive and jumping abilities in athletes specializing in middle-distance running, hurdles, jumping, and throwing, and we studied the relationship between the two abilities across all events. Nevertheless, there are varying records for each event in track and field; therefore, it is difficult to compare athletic level between events. To address this issue, in 2000, the International Association of Athletics Federations (IAAF) adopted scoring tables that were revised in 2014 (Aoki et al., 2015). While traditionally, the records for each event were ranked to compare them, using scoring tables it became possible to standardize competitive levels between events, which made them easier to understand. Studies using these IAAF

scoring tables have been published (Aoki et al., 2015; Legaz-Arrese, Munguía-Izquierdo, Carranza-García, & Torres-Dávila, 2011). We also used these scoring tables for our investigation in this study.

In addition to studying vertical jumping ability, which has been reported in prior studies, we studied the relationship with horizontal jumping ability (measurement variable) that can be easily performed during coaching to identify the correlation between effective jumping and competitive abilities in track and field.

Methods

Participants

The subjects were 137 male university athletes (age: 20.0 ± 0.9 ; height: 175.4 ± 5.9 cm; weight: 70.7 ± 13.0 kg) specializing in track and field and belonging to a championship team from a national university. The events of specialization were short-distance ($n = 37$), middle-distance ($n = 18$), hurdling ($n = 19$), jumping ($n = 35$), and throwing ($n = 28$). This study was performed with approval (No. 24-47) from a research ethics review by the Juntendo University Faculty of Health and Sport Science Ethics Committee and conformed to The Code of Ethics of the World Medical Association (Declaration of Helsinki), which was printed in the British Medical Journal (18 July 1964). The subjects explained the purpose of the study orally or in writing. Next, their consent was confirmed in writing, and those who consented were enrolled as subjects.

Testing Procedures

Field tests were performed over three days in the first third of November for a four-year period from 2012 to 2016, which was the end of the competitive season. The subjects jogged and stretched for five minutes before measurements were taken. The measurements were performed after recovery from fatigue after the completion of the final competition of the season.

The competitive performance of each subject was his season best at the time of measurement. This best record was compared against the IAAF scoring tables to convert it into a score. The IAAF scoring tables were designed by Spiriev by statistically analysing the competitive performance of track and field athletes around the world (Spiriev, 2014). Using these tables, it is possible to compare the competitive performance level between events. Currently, this method is advocated by the IAAF as a standard for international competitive performance, and it is being studied for scoring entry qualification points for international competitions in the future.

To evaluate jumping ability, we broadly divided the category into horizontal and vertical jumping, and the test items used were relevant measurement variables. For vertical jumping ability, we measured the vertical jump (VJ), squat jump (SJ), CMJ, and rebound jump (RJ); this approach is similar to that used in prior studies (Hudgins et al., 2013; Kale, Asçi, Bayrak, & Açıkada, 2009; Visnapuu & Jürimäe, 2009). All jumping exercises were performed on a mat switch (IFS-31D, DKH, Tokyo, Japan) to measure air time and contact time.

Using measured air time (Ta) and acceleration owing to gravity (g), we calculated the jump height (JH) using the formula ($JH = 1/8gTa^2$) developed by Asmussen and Bonde-Petersen (1974) (Asmussen & Bonde-Petersen, 1974).

The methods for measuring variables were as follows:

- Vertical Jump (VJ): Jump as high as possible with both legs while also using the arms.
 - Squat Jump (SJ): Jump as high as possible from a half squat position without using a rebound.
 - Countermovement Jump (CMJ): Jump as high as possible by dropping the hips from a standing position to a half squat and rebounding from that position. For this and previous tests, the jump is performed with hands against the hips to prevent using any rebound from swinging the arms. VJ, SJ, and CMJ were performed twice, and the measurement from the better of the two jumps was used.
 - Rebound jump (RJ) involved jumping five times in a row without bending the knees. While performing this test, the subjects attempted to minimize the ground contact time and jump as high as possible. The RJ-index was calculated by dividing the jumping height from the ground by the contact time. Of the five jumps, the highest obtained value was used for the RJ-index. Jumping ability in the vertical direction was measured at a gymnasium training area.
 - Jumping ability in the horizontal direction was measured using the standing long jump, standing triple jump, standing quintuple jump, standing 10-stride jump, and two-legged quintuple jump, which are used as simple methods during coaching (Aoki et al., 2015; Hennessy & Kilty, 2001; Misjuk & Viru, 2007).
 - Jumping ability in the horizontal direction was measured using a field with a sand pit for track and field.
 - Standing long jump was performed by jumping with both legs as far as possible from a standing position and landing in the sand pit.
 - Standing triple jump started from a standing position with a jump with both legs and then continued with two jumps with alternating legs and landing in the sand pit with both legs.
 - Standing quintuple jump continued with four jumps with alternating legs before landing in the sand pit with both legs.
 - Standing 10-stride jump continued with nine jumps with alternating legs before landing in the sand pit with both legs.
 - Two-legged quintuple jump started from a standing position with a jump with both legs, followed by four jumps (all with both legs) before landing in the sand pit with both legs.
- For these jumps, the distance from the toe tips (when starting the jump) to the heel position (when landing) was measured using a tape measure. The measurements were performed twice with the longer distance being used for the study.

Statistical Analyses

For all measured values for the scoring variables among all subjects, we calculated the mean, standard deviation, maximum, and minimum. Competitive performance was converted into a score, and we calculated the correlation (Pearson product-moment correlation coefficient) with each test variable. The statistical significance threshold was set at $p < 0.05$.

Results

Tables 1 and 2 show the mean and standard deviation for all events by event specialization.

Table 1: Subject attributes and measurement records

		Short distance(37)		Middle distance(18)		Hurdles 19)	
		M	SD	M	SD	M	SD
Height	cm	173.14	6.93	173.25	5.32	177.01	5.25
Weight	kg	64.91	5.29	60.81	4.56	67.46	4.76
IAAF score	points	909.05	117.42	908.00	98.83	931.42	98.41
VJ height	cm	57.95	7.35	51.66	4.64	56.68	5.56
SJ height	cm	41.95	4.80	37.11	3.83	39.95	4.16
CMJ height	cm	49.21	5.59	42.58	4.57	47.44	3.87
RJ-index		2.82	0.41	2.65	0.47	2.77	0.32
Standing long jump	cm	2.73	0.16	2.57	0.16	2.73	0.11
Standing triple jump	cm	8.08	0.48	7.46	0.64	8.16	0.33
Standing quintuple jump	cm	13.87	0.83	12.82	0.95	13.93	0.68
Standing 10-stride jump	cm	28.59	1.83	26.97	2.26	28.74	1.75
Two-legged quintuple jump	cm	13.55	0.97	12.35	0.66	13.39	0.70

Abbreviations: IAAF, International Association of Athletics Federations; VJ, vertical jump; SJ, squat jump; CMJ, counter movement jump; RJ, rebound jump

Table 2: Subject attributes and measurement records

		Jumping(35)		Throwing(28)		All events(137)	
		M	SD	M	SD	M	SD
Height	cm	175.31	4.37	178.79	4.76	175.40	5.89
Weight	kg	64.83	5.51	94.53	11.28	70.76	13.98
IAAF score	Points	984.77	78.97	829.93	67.77	915.19	107.97
VJ height	cm	60.60	6.69	57.20	10.19	57.47	7.84
SJ height	cm	44.14	5.38	40.34	5.17	41.27	5.32
CMJ height	cm	50.94	6.03	46.38	7.18	47.95	6.33
RJ-index		3.01	0.46	1.96	0.43	2.66	0.57
Standing long jump	cm	2.79	0.13	2.76	0.20	2.73	0.17
Standing triple jump	cm	8.47	0.47	8.07	0.55	8.11	0.58
Standing quintuple jump	cm	14.67	0.79	13.51	1.03	13.87	1.04
Standing 10-stride jump	cm	30.44	1.66	27.23	1.97	28.59	2.26
Two-legged quintuple jump	cm	13.86	0.92	13.92	1.16	13.53	1.06

Abbreviations: IAAF, International Association of Athletics Federations; VJ, vertical jump; SJ, squat jump; CMJ, counter movement jump; RJ, rebound jump; M, mean, SD, standard deviation

Tables 3 and 4 show the relationship between the IAAF scores and various types of jumping ability for each event and overall.

Table 3: Relationship between IAAF scores and jumping ability

	Short distance	Middle distance	Hurdles
VJ height	0.146	0.683 **	0.016
SJ height	0.298	0.167	0.433
CMJ height	0.386 *	0.369	0.530 *
RJ-index	0.248	0.083	0.312
Standing long jump	0.501 **	0.293	0.375
Standing triple jump	0.477 **	0.532 *	0.431
Standing quintuple jump	0.526 ***	0.519 *	0.412
Standing 10-stride jump	0.537 ***	0.553 *	0.135
Two-legged quintuple jump	0.480 **	0.206	0.211

Short distance n=37 * p<0.05: 0.325 ** p<0.01: 0.418 *** p<0.001: 0.519

Middle distance n=18 * p<0.05: 0.468 ** p<0.01: 0.590 *** p<0.001: 0.708

Hurdles n=19 * p<0.05: 0.456 ** p<0.01: 0.575 *** p<0.001: 0.693

Abbreviations: IAAF, International Association of Athletics Federations; VJ, vertical jump, SJ, squat jump; CMJ, counter movement jump, RJ, rebound jump

Table 4: Relationship between IAAF scores and jumping ability

	Jumping	Throwing	All events
VJ height	0.141	0.344	0.245 *
SJ height	0.348 *	0.197	0.343 ***
CMJ height	0.339 *	0.396 *	0.412 ***
RJ-index	0.388 *	0.204	0.462 ***
Standing long jump	0.294	0.364	0.332 ***
Standing triple jump	0.410 *	0.523 **	0.469 ***
Standing quintuple jump	0.531 **	0.496 **	0.546 ***
Standing 10-stride jump	0.427 *	0.399 *	0.551 ***
Two-legged quintuple jump	0.041	0.420 *	0.228 *

Jumping n=35 * p<0.05: 0.334 ** p<0.01: 0.430 *** p<0.001: 0.532

Throwing n=28 * p<0.05: 0.374 ** p<0.01: 0.479 *** p<0.001: 0.588

All events n=137 * p<0.05: 0.197 ** p<0.01: 0.256 *** p<0.001: 0.324

Abbreviations: IAAF, International Association of Athletics Federations; VJ, vertical jump, SJ, squat jump; CMJ, counter movement jump, RJ, rebound jump

For vertical and horizontal jumping ability, the most highly-correlated jumps with scores for each event were as follows. For short distance, it was CMJ height ($p<0.05$) and standing 10-stride jump distance ($p<0.001$); for middle distance, it was VJ height ($p<0.01$) and standing 10-stride jump distance ($p<0.05$); for hurdles, it was CMJ height ($p<0.05$); for jumping, it was RJ-index height ($p<0.05$) and standing 10-stride jump distance ($p<0.01$); for throwing, it was CMJ height ($p<0.05$) and standing triple jump distance ($p<0.01$).

The variables with a strong correlation with the IAAF score for all events were CMJ ($p<0.001$) and RJ-index ($p<0.001$) height among vertical jumping ability measures, and standing quintuple jump ($p<0.001$) and standing 10-stride jump ($p<0.001$) distance among horizontal jumping ability measures.

Tables 5 and 6 show the relationship between horizontal and vertical jumping abilities.

Table 5: Relationship between jumping measurement variables

	Standing long jump		Standing triple jump		Standing quintuple jump	
VJ height	0.606	***	0.593	***	0.617	***
CMJ height	0.666	***	0.689	***	0.688	***
SJ height	0.517	***	0.582	***	0.606	***
RJ-index	0.122		0.284	**	0.410	***

All events $n=137$ * $p<0.05$: 0.197 ** $p<0.01$: 0.256 *** $p<0.001$: 0.324

Abbreviations: IAAF, International Association of Athletics Federations; VJ, vertical jump, SJ, squat jump; CMJ, counter movement jump, RJ, rebound jump

Table 6: Relationship between jumping measurement variables

	Standing 10-stride jump		Two-legged quintuple jump	
VJ height	0.553	***	0.539	***
CMJ height	0.644	***	0.584	***
SJ height	0.577	***	0.454	***
RJ-index	0.487	***	0.033	

All events $n=137$ * $p<0.05$: 0.197 ** $p<0.01$: 0.256 *** $p<0.001$: 0.324

Abbreviations: VJ, vertical jump, SJ, squat jump; CMJ, counter movement jump, RJ, rebound jump

A high correlation between variables was obtained between CMJ height and standing triple jump ($p<0.001$) and standing quintuple jump ($p<0.001$). The strongest correlation with RJ-index among horizontal jumps was obtained with standing quintuple jump ($p<0.001$) and standing 10-stride jump ($p<0.001$) distances.

Discussion

Considering the relationship between short-distance running and jumping ability, which has been the subject of many previous studies, a strong relationship has been reported between short-term running records and CMJ (Karampatsos, Korfiatis, Zaras, Georgiadis, & Terzis, 2017; Loturco et al., 2015; Nagahara et al., 2014). In this study, we studied the relationship with the competitive records of short-distance athletes and similarly observed a relationship between short-distance competitive ability and CMJ ($p<0.05$). Furthermore, we observed a relationship with horizontal jumping ability in terms of standing triple jump ($p<0.01$), standing quintuple jump ($p<0.001$), and standing 10-stride jump ($p<0.001$). These results were comparable with those of prior studies (González-Badillo & Marques, 2010; Hennessy & Kilty, 2001; Kyriazis et al., 2010).

In our study, we not only included short-distance athletes, but also investigated whether the same trends could be observed in other event specializations. We determined that there was a correlation with CMJ in short-distance events ($p<0.05$), hurdles ($p<0.05$), jumping ($p<0.05$), and throwing ($p<0.05$). In recent studies, it has been reported that increased throwing performance correlated with increased CMJ height (Karampatsos et al., 2017; Kyriazis, Terzis, Boudolos, & Georgiadis, 2009). Our results suggested that CMJ is important not only for sprinting ability but also for jumping and throwing performance. Therefore, CMJ can be considered important in track and field for improving competitive ability and athlete conditioning.

The jumping ability that correlated the most with performance in each event specialization was standing 10-stride jump for short-distance events ($p<0.001$), VJ for middle distance events ($p<0.01$), CMJ for hurdles ($p<0.05$), standing quintuple jump for jumping ($p<0.01$), and standing triple jump for throwing ($p<0.05$). Among these, middle distance events were characterized by exhibiting a correlation with VJ height and not with CMJ, which differed from that of other event specializations. Among prior studies on middle-distance athletes, there has been a report on correlation with CMJ and squat jump (Bachero-Mena et al., 2017); however, our study produced results that differed from those in previous studies; we observed a correlation with VJ. Therefore, further investigation of the features of each event is necessary.

Our study used IAAF scores to investigate relationships with events, overall. We observed a stronger relationship with RJ-index ($p<0.001$) than with CMJ ($p<0.001$). The magnitude of RJ-index serves as an indicator for track performance. Furthermore, standing triple jump ($p<0.001$), standing quintuple jump ($p<0.001$), and standing 10-stride jump ($p<0.001$) exhibited correlations with IAAF scores. A prior study (Aoki et al., 2015) has demonstrated a correlation between standing quintuple jump and all events, which is the same result as that in our study. In addition, we observed a correlation with standing triple jump and standing 10-stride jump. Standing quintuple jump is particularly easy to implement and can be considered effective as a simple scale.

We investigated competitive performance and jumping ability in horizontal and vertical directions. Our results indicated a high correlation between CMJ and sprinting ability, which confirmed the results of prior studies (Hennessy & Kilty, 2001; Loturco et al., 2015; Bachero-Mena et al., 2017) and reinforced the validity of the measurement methodology. Prior studies typically use force plates; however, these devices are expensive and require specialized facilities. In contrast, a mat switch used in this study is inexpensive and can be used regardless of location; it can be used in the field, produces easy measurements, and provides highly reliable data. A prior study (Klavara, 2000) has stated that the "mat switch is capable of measuring a large number of people in a short period of time." Furthermore, the club that was the subject of this study consistently uses a mat switch to

perform measurements. Reeve et al. (Reeve & Tyler, 2013) have stated that “performing measurement using the same equipment via the same methodology leads to accurate measurements.” Therefore, continuing to use a mat switch in the future will produce highly reliable data.

We observed a correlation between CMJ and RJ-index among vertical jumping abilities. In addition, we observed a correlation between standing triple jump, standing quintuple jump, and standing 10-stride jump among horizontal jumping measures.

There are many prior studies measuring vertical jumping ability; however, our study is unique because we identified a number of highly reliable evaluation variables for horizontal jumping ability. Measuring horizontal jumping variables is an extremely simple method that can be widely applied to any subject. We observed a high correlation between CMJ and standing triple and quintuple jumps. The RJ-index correlated with standing quintuple and 10-stride jumps. Therefore, it is conceivable that standing triple, quintuple, and 10-stride jumps, which are highly correlated with CMJ and RJ-index, are effective as indicators that can be easily evaluated.

A future task is to study the relationship between horizontal and vertical jumping in greater detail and to use both measurement types to develop criteria for competitive performance.

Conclusions

CMJ, RJ-index, standing quintuple jump, and standing 10-stride jump are effective, common indicators with high correlations with competitive ability for track and field athletes in short-distance, middle-distance, hurdling, jumping, and throwing events. Furthermore, because the correlation between standing quintuple and 10-stride jumps and CMJ and RJ-index is high, these may be considered effective measurement variables that anybody can easily measure in the context of training approaches.

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Conflict of interest

All authors declare no conflict of interest.

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