Relationships Between Field Tests of Power and Athletic Performance in Track and Field Athletes Specializing in Power Events

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ABSTRACT

We investigated the relationships between power event scores and power/strength tests using the International Association of Athletics Federations (IAAF) scoring table. We sought to identify tests suitable for evaluating the performance of athletes specialized in power events involving different techniques (jumping, sprinting, and throwing). Seventy-four male university-level track and field athletes participated in this study. Standing triple jump, standing quintuple jump, and backward medicine ball throwing were positively correlated with IAAF scores in sprinters ($p < 0.05$), while forward medicine ball throwing, backward medicine ball throwing, and clean lift ($p < 0.05$) were associated with IAAF scores in throwers. Standing long jump ($p < 0.05$), standing triple jump, standing quintuple jump, and anaerobic power ($p < 0.001$) were positively correlated with IAAF scores in all athletes. Our results demonstrated that standing triple jump and standing quintuple jump were effective indicators of performance in power events in university-level athletes.

Key words: Jumping, IAAF Scoring Table, Sprinting, Throwing, Varsity Track and Field

INTRODUCTION

The typical scientific coaching method is to measure the athlete's physical strength and apply the results to a training program aimed at improving the athlete's performance. Previous studies have reported several methods of measuring physical strength and their results for a range of athletic events [1-3]. Physical strength is an important element in all sports, but it is important to use strength tests that take into account the characteristics of different sports.

Reviewers: Larry Judge (Ball State University, USA)
Yannis Pitsiladis (University of Brighton, UK)
Ray Stefani (California State University, Long Beach, USA)

Therefore, it is important to survey athletes specialized in various disciplines to clarify the relationship between athletic performance and physical strength.

There are 22 track and field events, of which 13 are sprinting, jumping, and throwing events that rely on power. Because the performance records differ between these events, it is very difficult to compare athletic performance among these events. The International Association of Athletics Federations (IAAF) addressed this problem by introducing a scoring table in 2000, which was revised in 2011 [4]. Before the introduction of the IAAF scoring table, performance was compared by ranking the athlete's performance within each event. It is now possible to compare performance levels across events using the IAAF scoring table, which provides a unified index for comparison.

Power/strength tests relating to track and field events have been developed and standardized to evaluate the effects of training for a particular event and developing training programs based on power/strength elements, for example [5-7]. Power events in particular rely on high levels of physical resources and skill. As the level of performance increases, techniques become more specialized, and physical elements become more important to achieve high levels of performance. Power athletes at the university level may need to achieve high power levels in common areas in order to improve performance.

In previous studies limited to power events, we investigated the correlations between athletic events (track and field events) and power/strength elements [8-12]. One problem identified in this series of studies was that, even within the same power event, it is not always possible to conduct the same test to compare performance. Without a common scale, it was impossible for us to measure the basic power/strength demands of these events. Until now, no studies have attempted to evaluate power tests that are applicable to all power events. The basic elements of power/strength common to high-power events are likely to become clearer if there is a common scale that can be used. It may be possible to overcome this problem by determining which power/strength tests are the most effective for evaluating common power/strength elements using IAAF scores.

The purpose of this study was to verify whether there are any power/strength tests that predict power/strength elements common to power events based on different techniques using IAAF scores as the outcome measure. Such data should help researchers to search for power/strength elements common to all power events after eliminating the technical components. The elucidation of these elements could help to identify prospective talents based on power/strength tests.

Although our study subjects were drawn from top university teams in Japan, very few athletes specialized in the same events. Therefore, use used the IAAF scoring table to convert athletic performance in different events into a unified scale. In this way, power characteristics were compared between track and field events grouped into blocks of related events, with the objectives of determining whether field tests of power differed among blocks of athletes and identifying tests that could be used effectively across all blocks. Another objective of this study was to investigate which power/strength tests could be used across all power-based events.

METHOD

SUBJECTS

Seventy-four males belonging to a university track and field team participated in this study. The mean ± standard deviation (SD) age, height, and weight were 20.0 ± 1.1 years (range, 18–24 years), 176.0 ± 5.5 cm (range, 162.0–191.1 cm), and 73.2 ± 14.5 kg (range, 52.0–124.0 kg), respectively. All of the subjects were university students majoring in sports science and trained every day. The subjects were categorized into three blocks: sprinters (*n* = 33), jumpers (*n* = 20), and throwers (*n* = 21). This study was approved by the ethics committee of Juntendo University School of Health and Sports Science (No. 22-29). Potential candidates were given a verbal or written explanation of the study objectives, and those who gave written, informed consent to participate were enrolled.

PROCEDURE

Field tests were conducted over 3 days at the end of the athletics season in November 2009 and 2010. The subjects were at the end of a 1-week transition period between the competitive season and the off-season, and were not performing any heavy physical training at the time of the study. The subjects completed a standard warm-up program before the field tests, beginning with a 5 min jog. Then, the subjects performed 5 min of skipping as dynamic stretching. The subjects completed one or two trials for each test. Regarding nutrition, hydration, sleep, and physical activity, the athletes were instructed to prepare themselves as they would for a regular competition, including abstaining from high-intensity training for 2 days before testing. The season's best score for each subject at the time of testing was used as a marker for that subject's athletic performance, and was converted to a unified score using the IAAF scoring table. The IAAF scoring table was developed by statistically analyzing the athletic performance of track and field athletes worldwide [4]. By converting athletic performance across different events to a single score, this table allows coaches and researchers to compare athletic performance levels between events. The table is recommended by the IAAF as an international index of athletic performance and is used by many national athletics bodies.

The field tests used in this study showed good validity and were easy to perform on the coaching ground. The tests were standing long jump, standing triple jump, standing quintuple jump, medicine ball throwing (backward and forward), leg extension power, anaerobic power, and maximum clean lift.

The standing long jump involved jumping as far as possible from a standing position using both feet and landing in a sandpit. The standing triple jump began with a jump from the standing position using both feet and comprised a hop (the athlete took off on one foot and landed on the same foot), a step (the athlete took off on one foot and landed on the opposite foot), and a jump (the athlete took off on one foot and landed on both feet). The standing quintuple jump started with a jump from the standing position using both feet, took four steps, and landed on both feet in a sandpit (Fig. 1). The standing quintuple jump with both feet started with a jump from the standing position using both feet, followed by four jumps with both feet, and landing on both feet. In all jumps, the distance from the toe at the start of the jump to the heel on landing was measured in meters. Each jump was performed twice, and the longest distance was recorded.

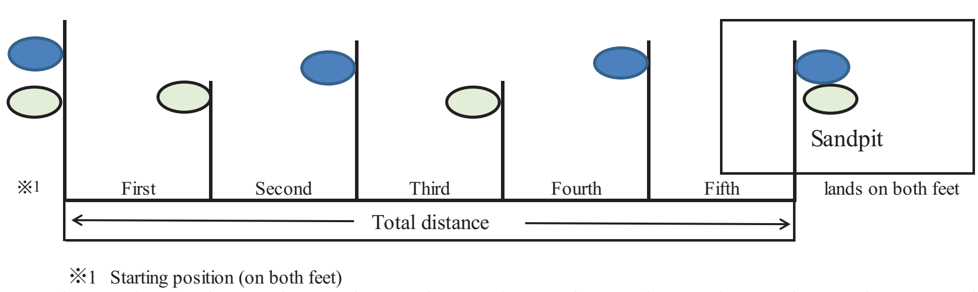

Figure 1. Protocol of the standing quintuple jump

Forward and backward medicine ball throwing was done using a 4 kg medicine ball. For the forward throw, the subjects stood on a reference line facing forward. They held the ball with both hands, and threw the ball forward using the whole body. For the backward throw, the subjects stood with their back to the reference line. They held the ball with both hands and threw the ball backwards using the whole body. The shortest distance from the reference line to the point where the ball landed was measured in meters. Each throw was performed twice, and the longest distance was recorded.

Leg extension power was measured using a leg extension power measurement system (Anaeropress3500; COMBI WELLNESS, Tokyo, Japan). With the subject's body weight as the load, the subjects sat with both legs bent and pushed a footplate forward with the maximum effort using the plantar part of the foot. This was done five times, and the mean of the two greatest values was taken as the maximum power (in watts) [13]. The clean lift was done by lifting from the hang position, and the one-repetition maximum was measured in kilograms.

Anaerobic power was measured using a cycle ergometer (POWERMAXVII; COMBI WELLNESS, Tokyo, Japan). The subject pedaled at full power for 10 s in each of three stages at loads selected based on the subject's body weight. The maximum anaerobic power (in watts) was estimated [14].

STATISTICAL ANALYSES

The mean, SD, and range were calculated for the field test scores for all subjects. Multiple comparisons among each block were done using one-way analysis of variance with Tukey's method. Athletic performance was converted to IAAF scores, and Pearson's product-moment correlation coefficients between IAAF scores and field test scores were calculated. The significance level was set at $p < 0.05$.

RESULTS

The IAAF scores and results of performance tests are shown in Table 1-1 for all subjects combined and in Table 1-2 for each block, together with the statistical comparisons of each test. Sprinters and jumpers differed in terms of anaerobic power relative to body weight. The results of many tests in throwers differed from those in sprinters and jumpers.

Table 1-1. IAAF Score and results of performance tests in all athletes ($n = 74$)

Variable	Mean ± SD	Range
IAAF score	894.1 ± 100.1	648–1084
Standing long jump (m)	2.69 ± 0.16	2.16–3.19
Standing triple jump (m)	8.09 ± 0.56	6.60–9.46
Standing quintuple jump (m)	13.80 ± 0.98	11.60–15.80
Standing quintuple jump with both feet (m)	13.56 ± 0.80	11.95–15.92
Forward medicine ball throwing (m)	13.44 ± 1.40	9.50–17.30
Backward medicine ball throwing (m)	14.09 ± 1.85	10.45–20.10
Leg extension power		
Absolute value (W)	2392.4 ± 507.6	1250–4290
Absolute value/body weight (W/kg)	33.00 ± 5.48	19.9–45.6
Anaerobic power		
Anaerobic power absolute value (W)	1135.6 ± 196.4	728–1919
Absolute value/body weight (W/kg)	15.7 ± 2.2	10.8–21.1
Maximum power clean weight (kg)	93.9 ± 20.0	60–150

IAAF, International Association of Athletics Federations; SD, standard deviation

Table 1-2. IAAF Score and results of performance tests in sprinters, jumpers, and throwers

Variable	Sprinters (n = 33)		Jumpers (n = 20)		Throwers (n = 21)		Significance
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	
IAAF score	920.5 ± 85.4	694–1070	942.0 ± 88.3	775–1084	807.0 ± 74.6	648–943	S>T** , J>T**
Standing long jump (m)	2.72 ± 0.14	2.40–2.94	2.72 ± 0.13	2.51–3.05	2.62 ± 0.19	2.16–3.19	
Standing triple jump (m)	8.12 ± 0.54	6.60–9.02	8.35 ± 0.44	7.30–9.24	7.81 ± 0.55	6.90–9.46	J>T**
Standing quintuple jump (m)	13.88 ± 0.91	11.60–15.35	14.35 ± 0.80	12.18–15.61	13.17 ± 0.89	11.90–15.80	S>T*, J>T**
Standing quintuple jump with both feet (m)	13.43 ± 0.79	11.95–14.80	13.62 ± 0.74	12.46–15.67	13.72 ± 0.84	12.60–15.92	
Forward medicine ball throwing (m)	12.80 ± 1.25	9.50–15.00	13.44 ± 0.87	12.10–15.10	14.45 ± 1.43	11.30–17.30	T>S**, T>J*
Backward medicine ball throwing (m)	13.03 ± 1.27	10.45–16.40	13.97 ± 1.23	10.90–16.20	15.88 ± 1.77	12.50–20.10	T>S**, T>J**
Leg extension power							
Absolute value (W)	2160.2±343.5	1250–2788	2253.4±368.4	1442–2746	2889.9±492.4	2079–4290	T>S**,T>J**
Absolute value/body weight (W/kg)	33.0 ± 5.1	19.9–43.6	34.1 ± 5.5	22.3–42.5	32.0 ± 5.8	22.1–45.6	
Anaerobic power							
Absolute value (W)	1040.1±117.8	807–1273	1153.5±160.6	728–1348	1268.6±239.1	777–1919	T>S**
Absolute value/body weight (W/kg)	15.8 ± 1.4	13.6–19.3	17.4 ± 1.9	14.0–21.1	13.9 ± 2.3	10.8–20.9	J>S*,S>T**,J>T**
Maximum power clean weight (kg)	85.9 ± 11.9	70–121	81.9 ± 10.7	60–100	117.8 ± 16.3	90–150	T>S**, T>J**

IAAF, International Association of Athletics Federations; S, sprinters; J, jumpers; T, throwers

Differences among groups were assessed by one-way analysis of variance followed by the Tukey multiple comparison method (*$P < 0.05$ and **$P < 0.01$).

The correlations between IAAF scores and field test scores are shown in Table 2. In sprinters, standing triple jump, standing quintuple jump, and backward medicine ball throw were correlated with the IAAF scores ($p < 0.05$) (Figure 2). In throwers, forward medicine ball throw, backward medicine ball throw, and clean lift were significantly correlated with the IAAF scores ($p < 0.05$) (Figure 3). There were no significant correlations between field test scores and IAAF scores in jumpers.

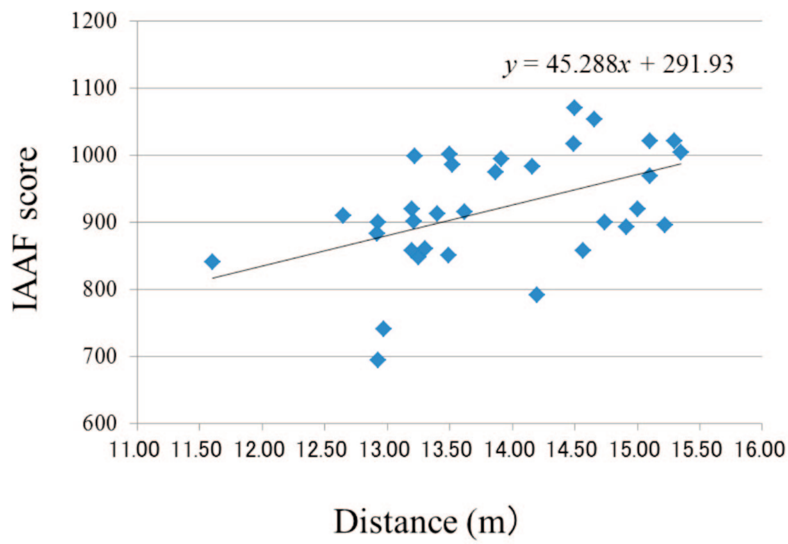

Figure 2. Relationship between IAAF score and distance jumped by sprinters in the standing quintuple jump ($n = 33$, $r^2 = 0.2348$, $p < 0.05$)

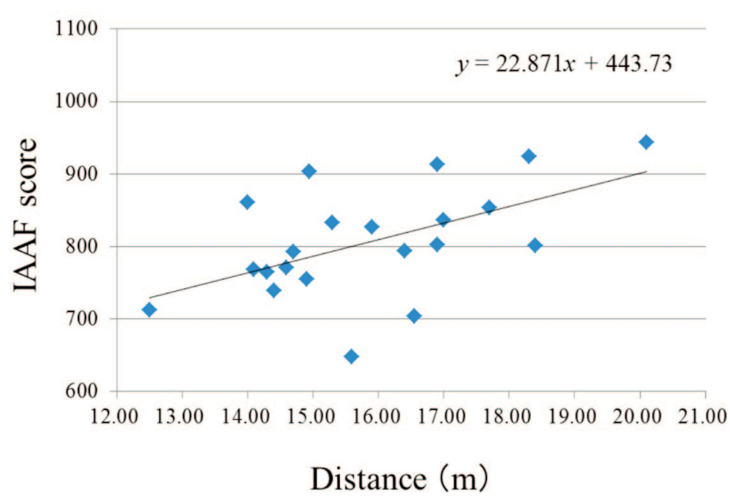

Figure 3. Relationship between IAAF score and distance thrown by throwers in the backward medicine ball throw ($n = 21$, $r^2 = 0.2929$, $p < 0.05$)

Table 2. Correlations coefficients between IAAF scores and results of performance tests

Variable	Sprinters $n = 33$	Jumpers $n = 20$	Throwers $n = 21$	All athletes $n = 74$
Standing long jump	0.30	0.04	0.15	0.29*
Standing triple jump	0.40*	0.24	0.23	0.43***
Standing quintuple jump	0.49*	0.34	0.16	0.51***
Standing quintuple jump with both feet	0.27	0.17	0.08	0.10
Forward medicine ball throwing	0.08	0.32	0.48*	–0.06
Backward medicine ball throwing	0.35*	0.21	0.54*	–0.08
Leg extension power absolute value/weight	–0.16	–0.03	0.29	0.07
Anaerobic power absolute value/weight	–0.02	0.04	0.19	0.35**
Clean absolute value/weight	0.34	–0.20	0.55*	–0.27*

*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$

In the total cohort of athletes, the standing long jump ($p < 0.05$) (Fig. 4), standing triple jump, standing quintuple jump ($p < 0.001$) (Fig. 5), and anaerobic power ($p < 0.01$) were significantly correlated with IAAF scores.

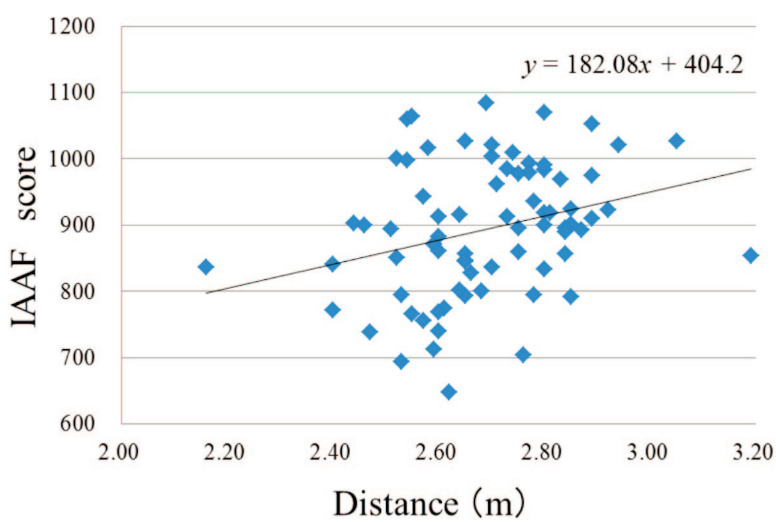

Figure 4. Relationship between IAAF score and distance jumped by all athletes in the standing long jump ($n = 74$; $r^2 = 0.086$, $p < 0.05$)

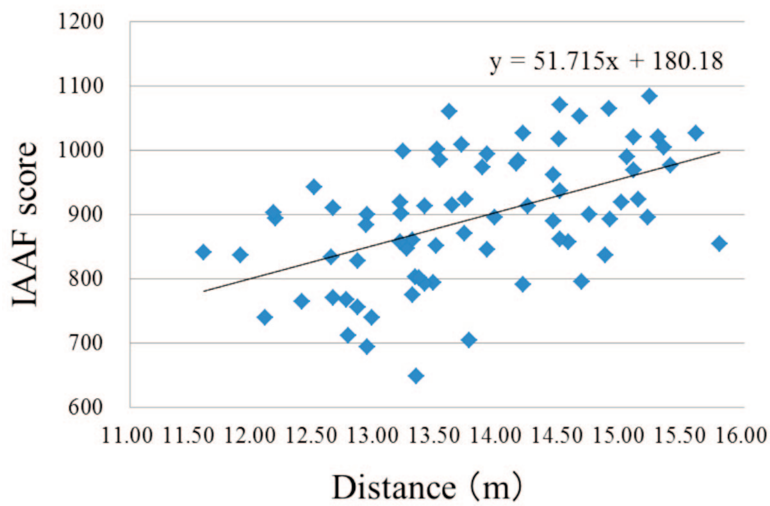

Figure 5. Relationship between IAAF score and distance jumped by all athletes in the standing quintuple jump (n = 74; r^2 =0.259, $p < 0.001$)

DISCUSSION

Previous studies focusing on athletic performance and physical strength in track and field events only included sprinters as the study subjects. Most of these studies investigated the relationship between sprinting performance and power, and the authors reported a strong association between sprinting performance and jumping performance, in particular [8-10, 11, 15]. However, in some studies, jumping performance was evaluated using a force plate in a laboratory or similar settings, or involved movement analysis [16-18]. Therefore, it is extremely difficult to apply these parameters to actual training setting, limiting their potential use in coaches or athletes.

In this study, we divided the 13 power-related track and field events into three blocks (sprinting, jumping, and throwing), and athletic performance in each block was converted to a unified scale using the IAAF scoring table. Based on the correlations between field test scores and IAAF scores, it was possible to determine which of the tests were correlated with performance in track and field events that rely on power. This approach allowed us to enrol athletes specializing in different track and field events despite the large number of events and the difficulty of collecting sufficient data for individual events. Another problem is that, although tests focusing on specific power elements of track and field events have been conducted in sports laboratories in prior studies, it is difficult for coaches to conduct such tests. In the present study, the field tests used to evaluate power included sandpit jumps, medicine ball throwing, anaerobic power determined on a cycle ergometer, and clean lift. These tests can be performed in coaching sessions without placing a burden on the athletes. Therefore, it is possible to select tests that are relevant to athletic performance in all track and field power events, allowing coaches involved in multiple events to offer power/strength tests that could be easily performed in coaching sessions.

The present results showed that the power level was a common element in sprinters and jumpers. However, sprinters and jumpers differed in terms of anaerobic power relative to body weight. This may be because the defining feature of jumping events is a single, large movement of the body. The power level of throwers also differed from that of sprinters and jumpers in each test, demonstrating that the elements of strength/power differed among the three blocks of athletes.

Considering each block individually, sprint performance was correlated with scores for standing triple jump, quintuple long jump, and backward medicine ball throw. The standing long jump (horizontal jump) is considered to be an effective marker of the potential performance of sprinters [19, 20]. Previous studies have also demonstrated a relationship between the standing quintuple jump and 30 m and 300 m sprints [10, 21], and between the standing quintuple jump and stride length [12]. In recent years, studies of university track and field athletes and football players concluded that the standing triple jump may be particularly important to short-distance races [22, 23]. A similar tendency was observed in the present study.

The correlation between medicine ball throwing and IAAF score was a novel finding. Medicine ball throwing has long been recognized as a reliable test for evaluation of whole-body power [24], and it is easy to perform by male and female athletes [25]. Conventional tests have focused on the legs, but the present results demonstrated for the first time that tests using the arms are also effective.

In jumpers, we found no significant correlations between the field test scores and IAAF scores. Sprint events cover different distances, but the mode of motion is similar for each distance. Furthermore, as described above, there was a correlation between power/strength test results and athletic ability in sprinters. By contrast, jumping events involve different maneuvers depending on whether the jump is horizontal, vertical, or uses a pole. Therefore, we would expect to encounter difficulties when evaluating the relationship between jumping events and power/strength tests. However, in a previous study [26], standing quintuple jump and forward medicine ball throwing were significantly correlated with results of horizontal jumping events in a large number of jumpers, with a similar trend observed in the present study.

In throwers, a previous study demonstrated a relationship between performance and jumping ability [27]. Although we observed a significant correlation between medicine ball throwing and clean lift, performance was not correlated with jumping ability. Clean lift is a typical weight event that requires power from the whole body. Prior studies confirmed that muscle strength was a major determinant of competition performance of elite throwers [28, 29]. A similar tendency was observed in the present study. The clean lift and medicine ball throwing tests were presumably effective because both tests involve the upper body, like throwing events. Throwing uses movements involving upper arm power that are not required for sprinting or jumping. Therefore, the tests reflect the movements involved in throwing events.

There have been very few studies involving a large number of subjects from several different track and field events. A prior study examined the timing of the start dash and relationship with counter movement jump in junior elite short-distance runners, jumpers, and decathletes (11 men, 9 women) [30]. Another study compared three kinds of counter movement jump using a force plate in sprinters and jumper [31]. However, neither of these studies evaluated athletic performance. In a third study, the authors examined the relationship between performance and anaerobic capacity (Wingate test) in elite male and female runners specializing in distances ranging from 100 m to the marathon [32]. The authors reported that the Wingate test is not useful tool for evaluating elite runners [32].

In the present study, we found that standing long jump, standing triple jump, standing quintuple jump, and anaerobic power were positively correlated with IAAF scores, whereas the clean lift was negatively correlated with IAAF scores. Earlier studies failed to detect a relationship between running ability and weightlifting capacity [33, 34]. Thus, it seems that jumping tests are effective markers of the potential performance of university athletes specializing in power events. In particular, we found that jumping ability is a common marker for all track and field events relying on power. A novel finding is that, of the jumping tests used in this study, standing triple and quintuple jumps showed stronger correlations with performance than did the standing long jump. This may be because, unlike the standing long jump, both the standing triple and quintuple jumps involve shifting the body weight using one leg, which resembles sprinting movements. Therefore, both tests appear to be useful markers of potential performance. Standing triple and quintuple jumps evaluate jumping power from one leg, and they can be considered more useful tests than standing long jump, which uses a two-leg take-off. Based on these results, we suggest that athletes should include the standing quintuple jump in training programs to improve performance.

Although previous studies did not use tests or introduced new tests to evaluate performance across different power events, by using the IAAF score, it is possible to evaluate the power/strength demands of athletes specialized in all power events using simple methods. In the present study, the performance levels were fairly uniform, and it was difficult to obtain a high degree of correlation. Nevertheless, the standing triple jump and standing quintuple jump tests were correlated with athletic performance in power events. The results of the present study showed that, although the subjects consisted of a group of top university athletes at the same level, the standing triple jump and standing quintuple jump tests involved a power/strength element common to all power events. These tests are very easy to measure and could be very useful for coaches involved in multiple disciplines, as a means of conditioning athletes, predicting athletic performance, and identifying talent. Because power events require a high level of skill, these tests could help coaches to identify prospective talent for power events among young athletes who have not yet mastered these skills. Further studies of subjects over a wider range of ages, events, and performance levels, including unskilled subjects, are needed to confirm the size of effect of this basic power/strength element.

CONCLUSION

In this study, we divided 13 power-related events into sprinting, jumping, and throwing blocks, and IAAF score tables were used to identify tests that represented common markers of athletic performance both within and across blocks. Our results confirmed that jumping tests and medicine ball throwing are effective markers of potential performance in university athletes. Medicine ball throwing and jumping ability in the standing triple jump and quintuple jump are inexpensive and simple to measure. Unlike tests that are traditionally performed in the sports laboratory, these tests can be easily performed in training sessions, and can be applied as field tests and used as markers of conditioning. As such, their application to coaching should be highly useful. Although track and field events are strongly related to power/strength, the highly specialized nature of each event means that there is little research in this context, and the effectiveness of power tests has not been demonstrated. Although we grouped the events into three blocks in this study, there was a clear relationship between athletic ability and power. We also demonstrated the significance and rationale for using power/strength tests in track and field coaching.

ACKNOWLEDGMENTS

We would like to thank all of the athletes who participated in this study and the reviewers for taking the time to critique this manuscript. This study was not supported by any external funding sources. We have no conflicts of interest to declare.

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