

Evaluation of explosive strength ability of the upper body for athletic throwers

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ABSTRACT

Physical fitness evaluation of throwing athletes has been performed based on measurement items for the purpose of power evaluation of the lower limbs and whole body; however, the method for assessing the muscle strength and exertion of the upper body has not been acknowledged extensively. The purpose of this study was to examine the effectiveness of the evaluation of the explosive muscle performance of the upper body of an athlete using several measurement parameters, including push up jump (PJ), countermovement push up (CMPU) flight time, medicine ball throw (MBT), countermovement medicine ball throw, and one repetition maximum of the bench press (BP-1RM). The relationship between these measurement items and athletic performance as determined using the IAAF score was examined. Eleven male athletes training on a daily basis were enrolled. A significant positive correlation between MBT and athletic performance was observed, indicating the usefulness of physical fitness evaluation in athletes. Conversely, PJ and CMPU were not associated with athletic performance, suggesting that these parameters may be negatively affected by the subject's weight. Further, BP-1RM did not show a significant correlation with athletic performance, owing to the fact that the exertion characteristics of one repetition maximum do not reflect the shrinkage rate of the muscle required for throwing. It is recommended that athletes select an event wherein their weight positively affects the competitive ability and does not affect measurement parameters. Further, explosive muscle performance without counter movements maybe incorporated into the physical fitness assessment of athletes.

Keywords: Athletics thrower; Explosion; Push up; Medicine ball throw, Bench press.

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INTRODUCTION

Athletic throwing (shot put, discus throw, hammer throw, javelin throw) is a sport in which physical elements have a significant influence on athletic performance. However, the method of evaluating their physical fitness is not advanced.

It is known that the initial velocity of release is the most critical factor for the distance of Javelin throw (Tauchi et al. 2007) and the Discus throw (Bartlett, 1992) and hammer throw (Hunter and Kiggore, 2003). It has also been reported that the shot-put distance and the initial velocity of the shot are highly correlated ($r = .921$) (Sugmar 2014). As these show, athletics throwing is recognized as the most critical factor in the initial velocity of the release.

Owing to the characteristics of the throwing competition, a large power performance is required (Zatsiorsky et al., 1981). Consequently, it is important that the training in consideration of its specificity is selected (Bartonietz, 2000); this has been implemented to enhance and demonstrate the ability of power in the practice field.

Field tests are conducted for one purpose - to evaluate the appropriateness of these training methods. They consist of events that reflect the specificity of the competition, such as throwing, standing long and triple jumps, 30 m sprint, shot back throw, and power evaluation by bicycle pedalling. These field tests have been performed from the 1980s to the present day, and the reliability of their evaluations has been reported (Jones, 1987; Borgstrom, 1989; Takanashi et al., 2009; Aoki et al., 2015). However, while many reports evaluated the power ability of the lower or intact body, few studies evaluated the explosive strength of the upper body (Zaras et al., 2016). In recent years, physical fitness evaluations, focusing on the upper body, have been reported in fields other than athletics (Hammami et al., 2019; Parry et al., 2019; Wang et al., 2017; Zalleg et al., 2018). Currently, the one-repetition maximum bench press (BP1-RM) is frequently used for the physical fitness evaluation of the upper body of athletic throwers (Victor and Artur 2003; Hatakeyama et al., 2011; Takanashi et al., 2020). However, the study results do not match; with the one-repetition maximum of the bench press; it can only be performed at a low speed; therefore, it does not sufficiently reflect the explosive strength and exertion required from the athletic throwers (Hatakeyama et al., 2011). In relation to these, the maximum strength is key in the athletic throwers (shot put); however, it is suggested that quick lifting is equally important (Terzis et al., 2007). It is necessary to consider the motor characteristics to evaluate the explosive strength and exertion required for throws. However, the method of evaluating the explosive strength and ability possessed by athletic throwers is unverified; nevertheless, it is an important issue in the practice field. Therefore, this study examined the effectiveness of explosive strength and ability using push-up operation and medicine ball throwing concerning athletic performance.

It is expected that there will be a highly significant positive correlation between upper body power and athletic performance. However, since there is no established method for assessing the physical fitness of the thrower's upper body, there is no confirmation. Coaches and athletes must assess fragmented fitness factors and incorporate them into their training plans. However, it is difficult to judge whether the physical strength of the upper body has improved by the conventional method of evaluating the lower body and the whole-body power. The novelty of this study is to evaluate the ability of the upper body only, without interlocking the forces generated by the lower body.

MATERIAL AND METHODS

Participants

The participants comprised of 11 male university-level athletes with an average age of 19.8 ± 0.9 years. The characteristics of the subjects are as indicated in Table 1. The athletes of the event included one shot putter, one discus thrower, six hammer throwers, and three javelin throwers. The most outstanding record of the 2019 season was scored using the International Association of Athletics Federation's (IAAF) scoring table.

Table 1. Characteristics of subjects.

	Mean \pm Standard deviation	Range
Age, y	19.8 ± 0.9	18-21
Height, m	178.60 ± 5.42	170.0-186.0
Mass, kg	94.90 ± 16.54	75.15-135.0
IAAF Score	775.18 ± 103.45	705-914
		n = 11

There are a limited number of junior athletes per university team. Although the number of participants in this study was small, we decided to increase the number of participants in the future based on the basic data obtained in this study.

Measures

Push up jump

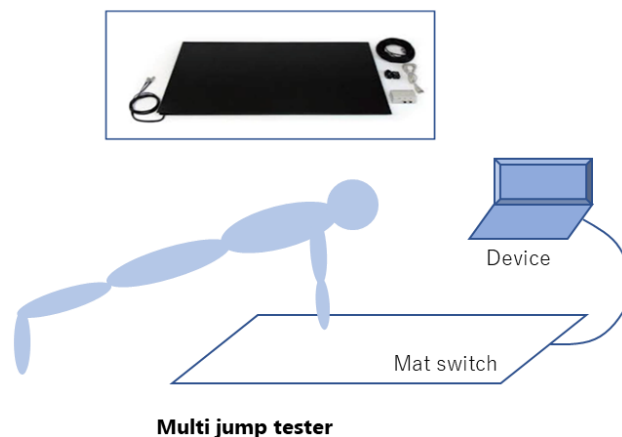


Figure 1. Multi-jump tester utilized for push up jump and countermovement push up assessments.

The purpose of Push up Jump (PJ) was to measure the explosive force of a simple muscle, which does not include the stretch-shortening cycle (SSC) or technical elements. The PJ measurement was implemented with a mat switch (DKH multi jump tester: Figure 1). The mat switch is a jumping power-measuring device equipped with a mechanism that functions by pressure. This is generally a system for calculating the height, such as vertical jump based on the airtime; it is widely used as a simple and accurate measurable device in the practice site (Zushi et al., 1993; Takanashi et al., 2019). The flight time (T_a) is recorded at the time of jumping; the jump height (h) = $1/8 g T_a$ (Zushi et al. 1993). Implementation image of PJ shown in Figure 2.

The elbow was bent from the position of the push-up training to 90 degrees, and it was made to leap without countermovement. The upper body was leaped by explosively extending the elbow. The time from the moment the hand left the mat switch until the hand landed after the leap was measured as the airborne time. During jumping, it was defined that the position of the foot does not change and that the hip joint bends only slightly. The hand was a little wider than the shoulder. We instructed the measurer to jump as high as possible. Before the measurement, we practiced on another day when fatigue did not affect us. The measurement was performed twice, and the record of the better one was adopted as the measured value.

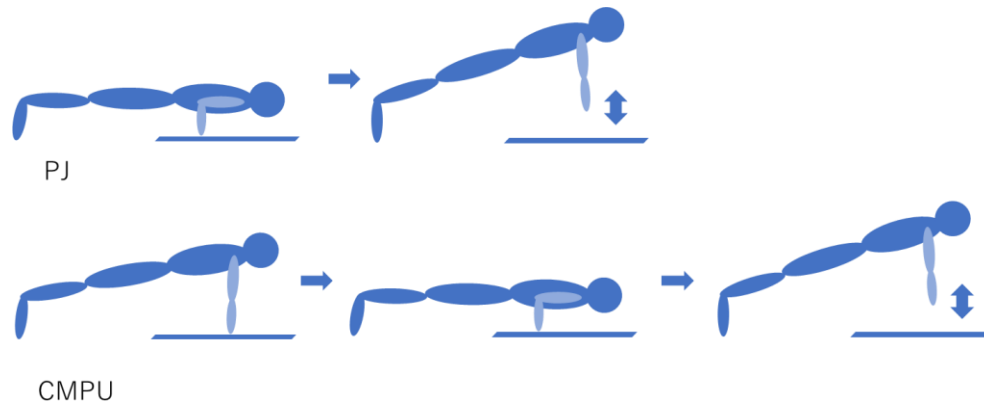


Figure 2. Push up jump (PJ) and counter movement push up (CMPU).

Countermovement push-up

The counter movement push-up (CMPU) was performed to measure the explosive force with SSC and technical factors. CMPU implemented a mat switch, as well as a PJ. This is as shown in Figure 2. The participant was made to leap upward using the counter movement operation from the posture of the push-up training. The hand was a little wider than the shoulder. The attempt was recorded twice, and the record of the better one was adopted as the measured value.

Medicine ball throw

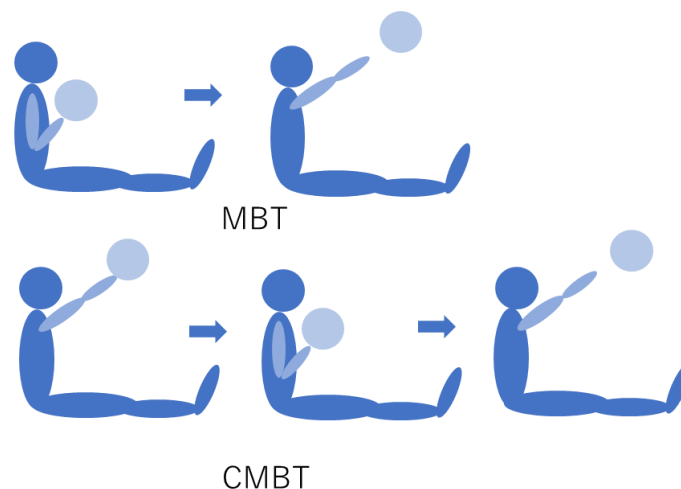


Figure 3. Medicine ball throw (MBT) and Counter movement medicine ball throw (CMBT).

Medicine Ball Throw (MBT) was performed to measure the simple explosive force of muscle without SSC or technical elements. The difference with PJ is that it is less susceptible to the adverse effects of participant weight. The implementation image of MBT is shown in Figure 3. The ball was held to the chest from the back in contact with the wall and passed to the front without a counter-movement. The record started from the wall, and the distance was assumed to the point where the ball fell. Both events were recorded with the back against the wall at the time of projection. These trials were measured twice with a 3-kg medicine ball, as used in previous studies (Hammami et al., 2019). Of the two measurements, the better one was used as the measurement value.

Countermovement Medicine ball throw

The Countermovement Medicine Ball Throw (CMBT) was performed to measure the explosive force of muscles with SSC and technical factors. The difference with CMPU is that it is less likely to be negatively influenced by the weight of the participant. The CMBT is as shown in Figure 3. This is a countermovement to MBT, concerning the exerting force (Bobbert et al., 1996). From the stretch of both arms holding the ball, he was shot using a reaction that drew to the chest. The measurement method was the same as MBT. Of the two measurements, the better one was used as the measurement value.

Bench press

The one-repetition maximum bench press (BP-1RM) is currently used to evaluate the physical fitness of the athlete. It was measured to examine the relationship between each measurement event attempted in the present study. The bench press adopted the increased weight until the elbow extended; afterward, the bar set on the bench rack was gradually released, until it touched the chest (Figure 4). This measurement is a habit for the participants in this study. Therefore, it was measured by one supervisor at any time during the measurement period. The highest value among the measured values was adopted.



Figure 4. Repetition maximum of Bench press (BP-1RM).

Procedures

All subjects understood the purpose and method of this study and provided consent in the written form. The use of measurement data for research was approved by the Ethics Review Committee of the Faculty of Sports and Health Sciences, Juntendo University (31-30).

All measurements related to this study were performed on the Sakura Campus Inzai city Chiba Japan of Juntendo University in February 2020.

All measurements were performed by the same supervisor with the assistance of co-workers.

Analysis

The relationship between the athletic performance and each measured event was examined using Pearson's correlation coefficient. The significance level had a difference of less than 5%.

RESULTS

Relationship between Athletics performance and Measurement events

The measurement results are as shown in Table 2. PJ readings were 0.342 ± 0.082 sec. No significant correlation was observed between PJ and IAAF Score ($r = -.330$, ns) (Figure 5). The CMPU measurement was 0.389 ± 0.074 sec. There was a significant negative correlation between CMPU and competitive power ($r = -.574$, $p < .05$) (Figure 6). MBT readings were 5.81 ± 0.73 m. A significant positive correlation ($r = .635$, $p < .05$) (Figure 7) was observed between the athletic performances. CMBT was 5.93 ± 0.68 m. There was no correlation between CMBT and athletic performance ($r = .502$, ns) (Figure 8). BP-1RM readings were 126.36 ± 28.62 kg. There was no significant correlation between BP-1RM and athletic performance ($r = -.019$, ns) (Figure 9).

Table 2. Results.

	Mean \pm Standard deviation	Range
PJ, sec	0.342 ± 0.082	0.199-0.444
CMPU, sec	0.389 ± 0.074	0.240-0.488
MBT, m	5.81 ± 0.73	4.6-7.1
CMBT, m	5.93 ± 0.68	4.8-7.1
BP-1RM, kg	126.36 ± 28.62	95.0-200.0
		n = 11

Note: BM: Body Mass, PJ: Push up jump, CMPU: Counter movement push up, MBT: Medicine ball throw 3 kg, CMBT: Counter movement medicine ball throw 3 kg, BP-1RM: Bench press one repetition maximum.

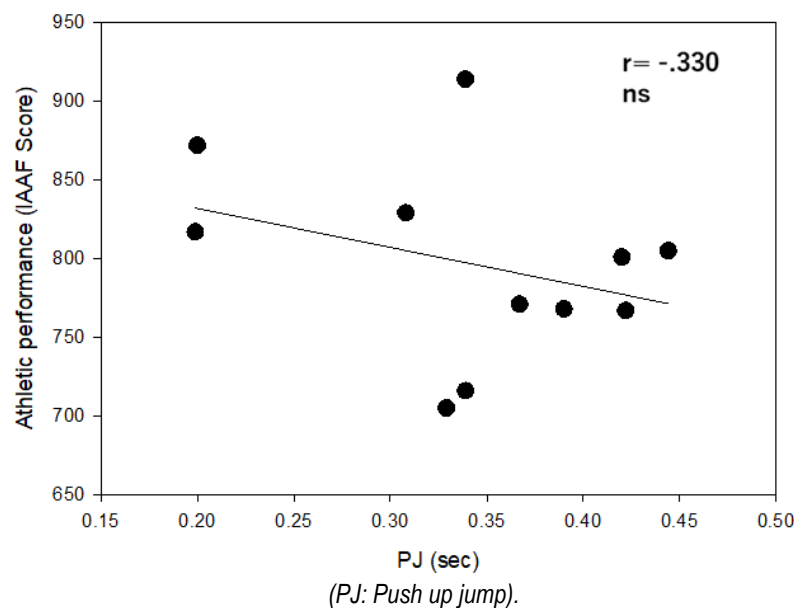


Figure 5. Correlation between IAAF Score and Push up jump.

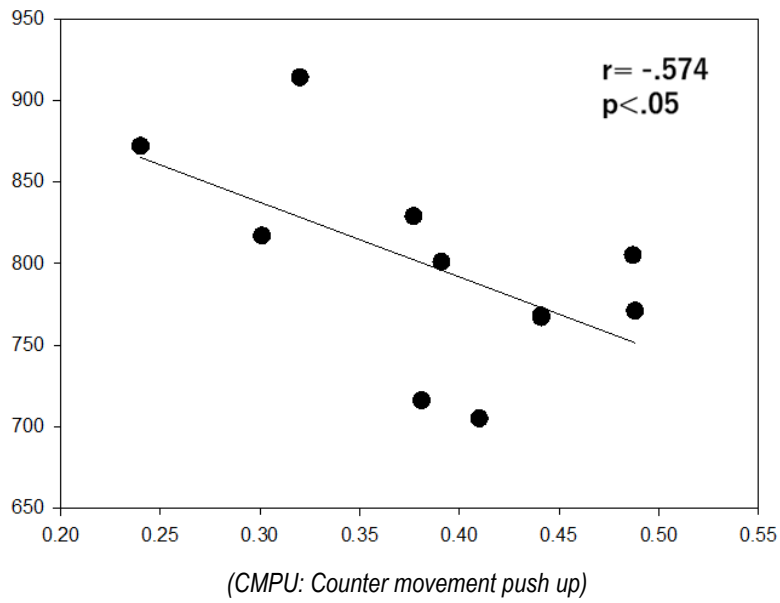


Figure 6. Correlation between IAAF Score and Counter movement push up.

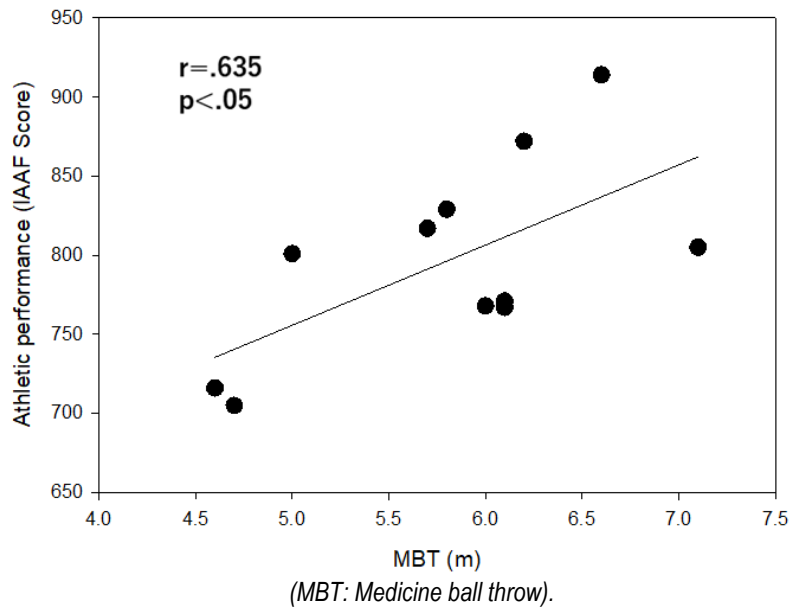


Figure 7. Correlation between IAAF Score and medicine ball throw.

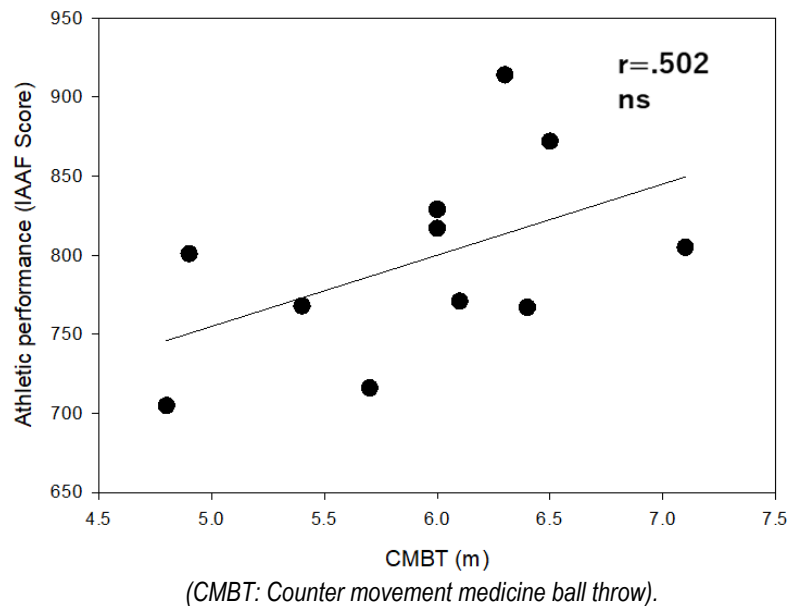


Figure 8. Correlation between IAAF Score and Counter movement medicine ball throw.

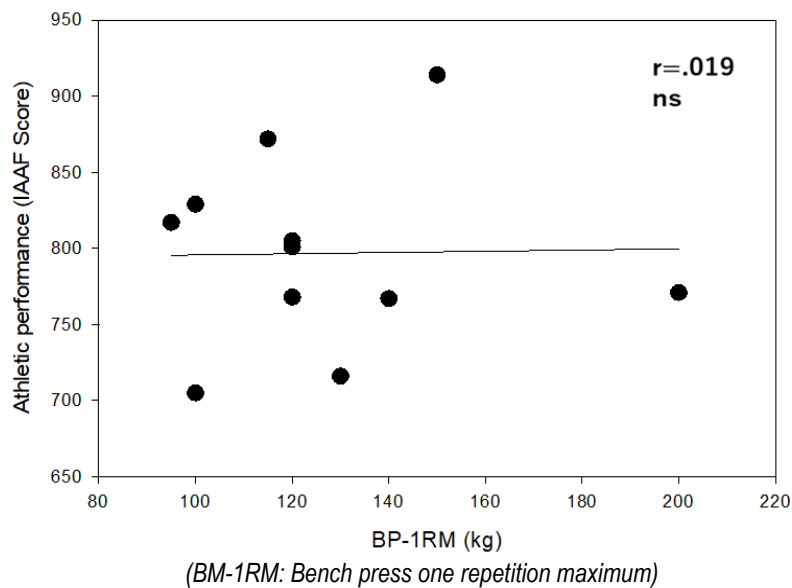


Figure 9. Correlation between IAAF Score and Bench press one repetition maximum.

Relationship between Measurement events

The relevance of each event is shown in Table 3. A significant negative correlation was observed between CMBT and body mass (BM) ($r = -.606, p < .05$), whereas a significant positive correlation was observed between CMBT and BM ($r = .645, p < .05$). BP-1RM was not significantly related to any of the events.

Table 3. Relationship between measurement types.

	BM	PJ	CMPU	MBT	CMBT	BP-1RM
IAAF Score	.547 †	-.330	-.574 *	.635 *	.502	.019
BM		-.497	-.606 *	.371	.645 *	.062
PJ			.836 **	.132	-.042	.358
CMPU				.103	-.024	.417
MBT					.835 **	.278
CMBT						.237

†: $p < .10$, *: $p < .05$, **: $p < .01$.

Note: BM: Body Mass, PJ: Push up jump, CMPU: Counter movement push up, MBT: Medicine ball throw 3 kg, CMBT: Counter movement medicine ball throw 3 kg, BP-1RM: Bench press one repetition maximum.

DISCUSSION

Relationship between PJ, CMPU, and Athletics performance

Parameters using ground reaction force have been reported for motion loads, similar to the push-up jump (Hinshaw et al., 2018; Koch et al., 2012). However, there are a few examples of verifying the effectiveness of the performance capabilities, for upper body physical fitness evaluation (Parry et al., 2019; Wang et al., 2017; Zalleg, 2018). A special device (force plate) is used on a large scale for these measurements; The force plate can accurately measure the ground reaction force during the exercise performed by the subject on the plate and can monitor it in real-time. However, many force plates are fixed in the laboratory; therefore, it is not realistically possible to regularly measure in the practice field. The practice field indicates the activity itself, not a place. Many junior athletes have a trial and error session with their coaches in the practice field. The laboratory results on competitiveness should be simulated on the practice field. Thus, it is important to provide research data quickly and accurately from the practice field. Therefore, the purpose of this study was to verify the relationship between the athletic performances, and the flight times of PJ and CMPU, with a device that can be utilized briefly in the practice field. However, no significant correlation was observed between the athletic performances and PJ ($r = -.330$, ns). In addition, there was a negative correlation between athletic performances and CMPU ($r = -.574$, $p < .05$); this cannot be deemed to be useful for the physical fitness evaluation of the athlete. In relation to this, a significant negative correlation between CMPU and BM ($r = -.606$, $p < .05$) was shown; it was considered that BM of the subject had a negative effect on the flight time of CMPU. In the present study, there was no significant correlation between competitive power and BM ($r = .547$, $p = .082$).

However, a direct correlation has been reported between BM and athletic performance (Maeda et al., 2018); the world's top athletes and their coaches (Babbitt and Hoffa, 2019) have emphasized the need to improve both weight and vertical jump ability. It is not challenging to visualize that a large physique is advantageous for the throwing competitor. In the results of the present study, BM tended to be higher than competitive power; this exerted a negative influence on the flight time. The motion similar to push-up jumping is effective for power evaluation (Parry et al., 2019; Wang et al., 2017; Zalleg et al., 2018). The average weight of the subject is 10 kg lighter than that in this study, with a difference in the BM (94.90 ± 16.54). Prior studies do not take into account flight time; since the ground reaction force is an index, the BM of the subject may function oppositely. Although the present study does not measure ground reaction forces, these are not in the realm of speculation; the importance of PJ and CMPU for athletic ability cannot be undermined. However, the airtime does not reflect the competitive power; the coach of the practice site should recognize the possibility of the negative effect sway by the weight of the subject.

Relationship between MBT, CMBT, and Athletics performance

According to the medicine ball data, a significant positive correlation was observed between the athletic performance ($r = .675$, $p < .05$) and MBT. In the case of vertical jumping, the most significant contributor to countermovement represented the increased time to exert power (Bobbert et al., 1996). All movements had a reverse reaction in the same magnitude; this was the result of larger forces working in the direction of gravity, resulting in greater vertical displacement (Waller et al., 2013). In the case of CMBT, a distance greater than MBT was recorded by the force in the opposite direction, and the projection direction of the medicine ball increased through the countermovement. However, the distance was found to be lower than a countermovement (Miura et al., 2002); the movement of the upper limb recoil effect by the SSC may not be as significant as the lower limbs. On the other hand, a significant correlation with the athletic performance and MBT was observed only after explosive throwing from a stationary state (MBT). This could reflect the ability of a simple explosion to be required of athletic throwers. As mentioned earlier, release velocity is very important to throwers. Therefore, it can be understood that quick and strong contraction of the muscle is required. It is noted as the rate of force development (RFD), i.e., how fast the muscle exerts its maximum power (Zaras et al. 2016-b). For muscle strength exertion of the lower body, a jump (squat jump) results in isometric activity, and the rising RFD is proven to be the maximum (Wilson et al., 1995). If this is replaced with the muscular activity of the upper body in the present study, the absence of MBT may reflect the most explosive muscle exertion ability.

The 3-kg medicine ball in the present study was, previously, employed to measure the physical fitness of handball players (Hammami et al., 2019). In the present study, a significant positive correlation between competitive performances was observed; tests employing 3-kg medicine balls were deemed to be effective. However, it may be suitable to handle a heavier ball; the appropriate weight of the ball may be verified in future studies. Medicine balls of five different weights were used for athletes to assess their physical fitness, prior to and post the 40-week training period (Zaras et al., 2016-a). It was reported that medicine balls weighing 1 kg, 2 kg, and 3 kg resulted in improvement during training, while those bearing 4 kg and 5 kg resulted in no improvement. Therefore, it can be said that the physical strength of the throwers may not necessarily be reflected with an increase in the weight of the ball.

Relationship between BP-1RM and Athletic performance

In the present study, there was no significant correlation between BP-1RM and athletic performance ($r = .019$, ns). Previous studies (Bourdin et al., 2010; Victor and Artur 2003; Hatakeyama et al., 2011; Takanashi et al., 2020) do not reflect a unified view. As it is possible to perform this bench press only at a low speed, it is considered that it does not sufficiently reflect the explosive muscular strength and exertion required of the athletic throwers (Hatakeyama et al., 2011).

All of these reports (Victor and Artur 2003, Takanashi et al. 2010) have a positive correlation between the one-repetition maximum of the bench press and the athletic performance. The inclusion of athletes and limited discipline characteristics (Victor and Artur 2003) is limited to shot put participants with an average of around 700 points when converted to IAAF Score. For Takanashi et al. (2020), the average was 728 points for a disc-throwing participant when converted to an IAAF score. When the IAAF Score reaches more than 700 points in the latter half, it reaches the advanced level that can be used in national level competitions. All advanced level athletes may have a certain level of strength and may not see a difference within the group.

Since this research is aimed at throwing athletes as a whole, it is not possible to refer to each specialty.

A previous study (Bourdin et al. 2010), which reported that there was a significant positive correlation between the performance of shot put, discus throw, and hammer throw and one-repetition maximum in bench press, was similar in competition level to the participants in this study. However, since the competition level is being examined by the achievement rate (%) against world record, it cannot be compared with the results of this study using the IAAF Score. It is a historical feature of projection competition that world records are the data recorded over 30 years from 1986 to 1990. Therefore, this result is questionable.

Since there is little evidence of the explosive muscle strength of athletic throwers in the upper body, a reference is made to studies from other disciplines. In other events, no significant correlation was observed between the raised height of the MBT in the upper direction, and the BP-1RM (Miura et al., 2002). It is presumed that this is another ability that is different from the ability to exert great strength and explosive muscle strength.

On the other hand, a significant correlation has been observed between the distance of the MBT and the climbing speed in the bench press of 135 lbs (James et al., 2010); There is no justification for setting the weight to 135 lbs in this study. However, this comprises about 66% of the average weight of the participant.

Empirically, 66% load on a bench press is as light as is used to enhance the speed at light loads. It is conceivable that the upward speed is deeply related to the ability to throw than the aforementioned weight. In addition, it is not desirable to merely evaluate the simple maximum weight (Terzis et al., 2007; Sakamoto et al., 2018). This suggests the importance of speed in weight training in the athletic throwers (shot put).

Other events (Discus throw, hammer throw, javelin throw) are similar to shot put because it involves throwing a relatively heavy object, and the initial velocity at the time of release is very important. Therefore, the speed of weight training elevation is likely to be important for all throwing events.

CONCLUSIONS

Explosive muscle ability is the ability to exert a relatively large amount of muscle power instantaneously. For the evaluation of the explosive muscle ability of the upper body of athletic throwers, the BP-1RM, the stagnation time in the push-up operation, and the effectiveness of the MBT assessment were examined, with respect to performance.

A significant direct correlation with the athletic performance was observed with the distance of MBT; the effectiveness of the physical fitness evaluation was confirmed. Measurements of PJ and CPMU were not related to the athletic performance, suggesting that the subject's BM may be negatively affected.

Further, BP-1RM did not reflect a significant correlation between the athletic performances; exertion characteristics of the maximum weight were unindicative of the shrinkage rate of the muscle required for the throwing competition.

It is a critical issue to raise both weight and jump ability in the practice field of the throw event. Therefore, athletes and coaches at the practice site should adopt a method of physical fitness evaluation that thoroughly considers the required athletic characteristics.

It is recommended an event is to be selected where weight positively affects competition and not the measurement results. Explosive muscle performance, without counter-movements, may also be incorporated into the athlete's physical fitness assessment.

AUTHOR CONTRIBUTIONS

Yuta Takanashi: Corresponding author, conception and design of the study, drafting the article and its critical revision. Yoshimitsu Kohmura: Data analysis and interpretation, drafting the article and its critical revision, final approval of the version to be published. Kazuhiro Aoki: Conception and design of the study, final approval of the version to be published.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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