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# ANALYSIS ON THE RELATION BETWEEN VELOCITY AND POWER VALUES DURING PROPULSIVE PHASE OF BENCH THROW EXERCISE AND UPPER-BODY STRENGTH CHARACTERISTICS IN PROFESSIONAL HANDBALL PLAYERS

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**Abstract:**
The purpose of this study is to analyze the relation between velocity and power values during propulsive phase of bench throw exercise and upper-body strength characteristics in professional handball players and to determine whether upper-body strength characteristics have a significant effect on velocity and power parameters. In accordance with this purpose, a total of 13 professional handball players competing in Turkish Handball 1. League (age: 25.4 ± 3.86 years; height: 187.5 ± 8.33 cm; body weight: 90.9 ± 14.8 kg) voluntarily participated in the research. In this study, maximal dynamic strength test was applied in bench press (BP) exercises in addition to the right and left hand grip strength test with the purpose of determining the upper-body strength characteristics. In order to determine velocity and power parameters, bench throw (BT) exercises were applied by using an external load that corresponds to 30% of body weights of the participants via an isoinertial velocity converter (T-Force dynamic measurement system) and values of mean propulsive velocity (MPV), peak velocity (PV), mean propulsive power (MPP) and peak power (PP) were obtained. Descriptive statistics, Spearman correlation analysis and Kolmogorov-Smirnov normality tests were used in order to analyze data. According to analysis results, while mean one-repetition maximal (1RM) strength values of the participants in BP exercise were obtained as 97.8 (± 15.0 kg), their right and left hand grip strength values were respectively obtained according to the order specified as 55.4 (± 8.16 kg) and 53.7 (± 5.81 kg). It has been concluded that while there is a statistically positive and significant relation between the MPV ($r = .674$, $p < 0.05$; $r = .698$, $p < 0.01$, respectively) and PV values ($r = .644$; $r = .670$, $p < 0.05$, respectively) of the participants in BT exercises and both right and left hand grip strength values, there isn't any statistical relation in terms of the MPP ($r = .528$; $r = .456$, $p > 0.05$, respectively) and PP values ($r = .487$; $r = .401$, $p > 0.05$, respectively). It has also been concluded that there is a statistically positive and highly significant relation

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between 1RM strength values in BP exercises of the participants and MPV (r = .728), PV (r = .775), MPP (r = .703) and PP (r = .759) values obtained during the propulsive phase of BT exercises ($p < 0.01$). As a result, it can be suggested that upper-body strength characteristic positively affects velocity and power parameters, velocity and power characteristics are dominant and provide a significant contribution to the performance and these results will contribute to trainers and conditioners while preparing training programs in sports branches.

**Keywords:** handball, propulsive phase, velocity, power, strength

## 1. Introduction

Handball is a strenuous and body-contact team sports in which players of two teams play both in offence and defense by turns (Sibila *et al.,* 2004), important emphasis is laid on jumping, throwing, running and running speed (Toyoshima *et al,* 1974) and substantial strength levels to hit, block, push and hold during matches are required (Gorostiaga *et al.,* 2006; Granados *et al.,* 2007). The energy required during a match is provided from both aerobic and anaerobic ways (Boraczynski and Urniaz, 2008). It is stated that strength, muscular power and throwing velocity at high level together with the characteristic of endurance are among the most important factors for successful participation in handball leagues at elite level (Gorostiaga *et al.,* 2005). For this reason, some additional resistances and conditions specific for handball should be arranged in addition to sprint and endurance trainings of players in order to improve their handball performance (Jensen *et al,* 1997). As players must have various technical skills (such as shooting and passing) and fitness components (such as the ability to jump, speed, strength and endurance) in order to reach high level in handball (Marques and Gonzales-Badillo, 2006; Buchheit *et al.,* 2009; Ingebrigtsen *et al.,* 2013).

Maximal strength defined as the highest force generated in a muscle or muscle group by neuromuscular system during a maximal contraction without any time limitation is denoted as one repetition maximal (1RM) or 100% of the maximal and indicates the heaviest weight an athlete can lift in one go (Bompa *et al.,* 2012). In literature, maximal strength is suggested to be one of the important factors that determine power efficiency during a task (work) performed against a submaximal load (Moss *et al.* 1997; Stone *et al.* 2003). Although the terms of strength and power are sometimes used in place for each other, this is a false approach. As the power being among the important factors of athletic performance has a time component and it is the mechanical amount defined as the temporal rate of the study performed (power = work / time) and it generally depends on the ability to create the highest strength (maximal strength) possible (Newton and Kraemer, 1994; Stone *et al.,* 2003). In other words, if two athletes have similar maximal strength, the individual who displays strength faster (or in shorter time) will have a certain advantage during the performance in anaerobic motions (Ratamess, 2012). Performance success in many athletic motions mostly depends on how much power will be applied to objects (ground, ball or sports equipment etc.) (Newton and Kraemer, 1994) and the success during a certain athletic work completed within a short time depends on the power efficiency capacity of the athlete (Baker, 2001). It is important to measure power for three different reasons. These are as follows; (1) determining the optimal load for resistance training, (2) evaluating the effect of power training and (3) predicting the exercise performance (Kobayashi *et al.*, 2013).

Muscle has a characteristic that can adjust the reaction force against a resistance applied to itself during a shortening. This characteristic that distinguishes muscle from a simple elastic object is based on a continuous adjustment of velocity generated by the muscle contraction system against an outer resistance (Edman *et al.*, 1978). It is highly important to apply force as soon as possible in athletic performance. Therefore, it is necessary to exhibit the highest force possible in a very short time for many motions that take place shorter than one second. The ability to display high velocity maximal strength in such motions is one of the most important factors that ensure success (Sale, 2003). Velocity being a vectorial quantity is the temporal rate of the change in positions (Zatsiorsky, 1998). The velocity of a muscle during concentric contraction is inversely proportional to the load applied or outer resistance. When the force applied is zero, the contraction velocity of a muscle is maximum. When the force increases to a level equivalent to the maximal strength that will force the muscle, contraction velocity becomes zero (Bartlett, 2007). In other words, the heavier the weight is, the more the force generated by the muscle becomes and the less the motion velocity becomes. This case is experimentally correct. If an athlete is requested to do bench press (BP) motions in an amount of possible maximal weight, the athlete will move the weight so slowly. But if athlete is requested to do BP within half of 1RM, the athlete will move the bar faster (Kraemer and Vinger, 2007). Motion velocity is a variable to which more interest can be attached in order to monitor the exercise intensity but it is interesting that motion velocity is mentioned in many studies in a limited way although some authors are aware of it (Pereira and Gomes, 2003; Izquierdo *et al* 2006). Perhaps, the actual velocity in every repetition can be the best reference for a true amount of effort exerted by the athlete (Gonzales-Badillo and Sanchez-Medina, 2010).

Throwing is accepted as one of the most important technical skills in competition-based team handball and it is the main determinant in all kinds of behaviors displayed by players (Zapartidis *et al.,* 2009). Throwing velocity is highly important for the success in handball. As the faster the ball is thrown to the target, the less time defenses and goalkeeper will have in order to clear the shot (Gorostiaga *et al.*, 2005). It is expressed that upper and lower extremity muscular force and power is the most important factor for an effective arm throwing velocity (Joris *et al.,* 1985). Moreover, the physical attributes of the athlete, technical skills and the coordination of body segments are among the important factors (Muijen *et al.*, 1991).

When we look at the literature, it is observed that the relation between different throwing techniques such as standing throw, basic throw or 3-step running throw with one-repetition maximal strength in BP exercise (Fleck *et al.*, 1992; Hoff and Almasbakk, 1995; Bayios *et al.*, 2001; Van Den Tillaar and Ettema, 2004; Gorostiaga *et al.*, 2005; Marques *et al.*, 2007; Granados *et al.*, 2007; Chelly *et al.*, 2010; Debanne and Laffaye, 2011) or the relation between lifting velocity in different weights for BP exercise and throwing velocity (Gorostiaga *et al.*, 1999; Marques *et al.*, 2007) have been analyzed in different studies. As far as we are concerned, there is no such study that analyzes the relation between velocity and power values during the propulsive phase of bench throw (BT) exercise and upper-body strength characteristics in handball players. It is thought that the results to be obtained from this study will provide a significant contribution to trainers, conditioners and sports scientists while preparing training programs. For this reason, the purpose of this study is to analyze the relation between velocity and power values during propulsive phase of bench throw exercise and upper-body strength characteristics in handball players and to determine whether upper-body strength characteristic has a significant effect on velocity and power parameters.

## 2. Material and Method

### 2.1 Participants

A total of 13 handball players from a professional sports club having minimum 5 years of sports history and competing in Turkish Handball 1. League voluntarily participated in this study (characteristics of the participants are given in Table 1). Medical condition of the participants is good and they don’t take any drugs that may negatively affect the analyzed variables. The participants and trainers were informed about the purpose of the study, test procedures, potential risks and benefits of the research in detail before the study and afterwards, the participants signed a written consent form stating that they voluntarily participated in the study. This study was approved by the Karadeniz Technical University Committee of Scientific Research Ethics and prepared in accordance with the Helsinki Declaration.

### 2.2 Experimental Approach to the Problem

All subjects in this research are composed of the athletes who completed strength training programs in the past. A typical weekly training program of this team contains 18 hours on average composed of branch-specific handball training programs (5 periods), physical condition training programs (3-4 periods and two of them are strength training) and competition (1 match a week). The participants were tested for two (2) consecutive days. On the first day, the participants were applied right and left hand grip tests and maximal dynamic strength test in bench press (BP) exercise. On the second day, bench throw (BT) exercise was performed by using external load equivalent to the 30% of the body weights of the participants. Due to the fact that all subjects have participated in comprehensive exercise programs in university’s condition center, they are quite used to test protocols. Before applying tests (BP and BT exercises), the participants completed a 20 minutes standard warm-up protocol containing 15 minutes general exercises (upper and lower body stretching for 5 minutes following the medium speed running) and special exercises for 5 minutes (BP and BT test at submaximal level). In this study, the reason for using BP in order to determine upper-body strength characteristic and for using BT exercise in order to determine velocity and power values during propulsive phase is that both motions are multi-joint exercises and they are commonly used to develop the upper body performance (Akagi *et al.,* 2014). BP is one of the mostly used exercises during training and testing of upper-body muscles (chest, arm and shoulder) and it is the most specific exercise to the overhead throwing in handball. For this reason, one repetition maximal (1RM) strength test was applied in BP exercise in order to evaluate the maximal strength of upper-body. Moreover, BP is used quite frequently in resistance training programs with the purpose of both increasing strength and improving throwing performance (Hoff and Almasbakk, 1995; Gorostiaga *et al.,* 2006). Due to the fact that a braking phase affecting the power efficiency occurs after the pressure during BP exercise, BT exercise frequently used for power efficiency measurement has been performed with the purpose of determining power and velocity values during propulsive phase (Kobayashi *et al.*, 2013).

**2.3 Procedures**

Anthropometric variables of every participant including height (m), body weight (kg), body fat mass (%) and muscle mass (%) were measured. Measurements of height and weight were obtained using a Seca 769 electronic measuring instrument (Seca Corporation, Hamburg, Germany) with an accuracy of one as 0.001 m and 0.01 kg according to the order specified. Body mass index (BMI) was calculated as per the body weight and height formula ($kg.m^{-2}$). Body fat percentage and muscle mass percentage was obtained by using body composition analysis device (Inbody 720 Bioempedans Body Composition Analyzer, Biospace, Seoul, Korea).

Hand grip strength values of the participants were measured from both right and left hand by using a digital tension dynamometer (Takei TKK5401, Takei Scientific Instruments, Tokyo). During the measurements, participants were allowed to stretch or extend their elbows on condition that they did not touch their arms or the dynamometer on their bodies. According to the standard arm position proposed by the American Society of Hand Therapists (ASHT) for hand grip test, the shoulders of the participants should be adducted and should be independently rotated, their elbows should be bent 90º, and sit in a way with the forearms and the wrists in a neutral position (Fess and Moran, 1981). Participants should be able to grasp the dynamometer with the dominant hand while standing and apply maximal pressure gradually for at least two seconds to get the degree. Non-dominant hand was measured after the results were recorded. The movable part of the dynamometer arm was set in a way to reach the first finger bone of the ring finger. Participants performed two maximal strength tests with both hands and the best results for both hands were recorded with an accuracy of 0.1 kg.

One repetition maximal BP test ($1RM_{BP}$) was applied on a Smith machine (Esjim IT7001, Eskisehir, Turkey) by using the procedure designed by Earle and Beachle (2008). In this procedure, participants lied back in the way that their heads, shoulders and hips were in contact with the bench and both feet were in contact with the floor (five point contact). The bar was grasped with a closed, pronated grip slightly wider than shoulder width. An assistant helped the participant lift the weight bar up to its starting position where the elbows were extended. For security, the assistant stood at a position close to the head of the participant holding the weight bar with the closed and alternative grip and followed the weight bar during the participant's raising and lowering the bar without touching it. Every repetition was started in this position. The participant lowered the weight bar to touch the chest until it reached the nipple level, and then lifted it continuously until the elbows were fully extended all the way. The participants were required to obey the five contact point rule during the move and not to bounce the bar from breast at the bottom of the movement (Moir, 2012). $1RM_{BP}$ values of the participants were obtained according to the procedure designed by Beachle *et al.*, (2008).

The operations of this procedure are explained below in detail.

1. After a 10-minute general warm-up, the participants were warmed up with a load allowing 5-10 repetitions.
2. One (1) minute of rest was given.
3. A warming load was calculated which allowed the participants to repeat 3-5 times by adding a weight of 7 to 9 kg to the load used in the 1$^{st}$ step.
4. Two (2) minutes of rest were given.
5. A load close to the maximal was calculated which allowed the participants to repeat 2-3 times by adding a weight of 7 to 9 kg to the load used in the 3$^{rd}$ step.
6. Three (3) minutes of rest were given.
7. 1RM attempt was performed by adding a weight of 7 to 9 kg to the load used by participants in the 5th step.
8. Three (3) minutes of rest were given.
9. When the subject was successful at lifting the weight at the 7$^{th}$ step, it was continued after the load was increased at a reasonable rate. However, the weight was lifted after reducing the load between 3 to 5 kg when the subject failed in 1RM attempt.
10. Three (3) minutes of rest weren't given.
11. Increasing and reducing the load was sustained until the subject completed one repetition maximal with an appropriate technique and 1RM strength value of the subject was determined in maximum 5 trials.

Velocity (MPV: mean propulsive velocity and PV: peak velocity) and power (MPP: mean propulsive power and PP: peak power) parameters during propulsive phase of the BT exercise was obtained from a Smith machine (Esjim IT7001, Eskisehir, Turkey). The reason for the use of a smith machine instead of the free weights to ensure correct and reliable measurements in the BT exercise is that this device limits the movement in the vertical direction (Kobayashi *et al.*, 2013). The participants were told to perform BT exercise for 3 times at maximal velocities by using an external load equivalent to the 30% of their body weights. During the BT exercise, participants were asked to lower the bar in a controlled manner until they touched slightly on their chest, and then they would have to launch it as fast and high as possible with the start command (Loturco *et al.*, 2014). To determine velocity and power parameters, a linear converter (T-Force Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was connected to the last section of the bar. The use of this system is particularly well suited for any resistance training exercise where it is required to overcome typical weight lifting exercises or a load (constant mass) moving along a vertical axis against gravity. The system includes an electromechanical hardware (speed sensor and interface), a special computer program (T-Force system software) that manages this hardware and a hook that connects to weight training barbell. The velocity sensor is usually placed on the ground and measures the velocity of the lifted loads by measuring how quickly the 2 meter cable is pulled and dropped through a tachogenerator with a high sensitivity within the aluminum body. In other words, the sensor provides flow with a direct proportion to the movement of the cable and ensures direct determination of the velocity at which the movement is made. The cable is made of nylon-coated stainless steel and has a diameter of 0.50 mm. The wire voltage is can withstand large accelerations (5 N) and therefore it is not a problem to use this system for sudden sports movements such as vertical jump, pull and lift. The computer transmission interface includes an electronic data acquisition kiosk equipped with 14-bit resolution. It is connected to the computer via a USB port that allows very fast and reliable data transfer. The sampling frequency of data obtained is fixed at 1.000 Hz. This means that instantaneous velocity data in each ms is obtained. A specially designed hook is used to connect the training weights to the power converter cable (Sanchez Medina *et al.*, 2010, 2014).

### 2.4 Statistical Analysis

All variables are expressed as mean and standard deviation. Normality distribution of the variables has been evaluated by using Kolmogorov -Smirnov test. Spearman's correlation coefficient analysis has been used to investigate the relation between velocity and strength values during the propulsive phase of the BT exercise and participants' upper body strength characteristics and anthropometric attributes. SPSS version 16.0 (SPSS Inc, Chicago, IL) has been used for all statistical calculations. $p < 0.05$ value has been accepted as the significance level.

## 3. Results

The results for some physical and anthropometric characteristics of the participants are summarized in Table 1. Table 2 shows the participants' upper-body strength characteristics and parameters for some variables obtained during the propulsive phase of the BT exercise. As can be seen in Table 2, mean $1RM_{BP}$ strength values of the participants have been obtained as 97.8 (± 15.0 kg); right and left hand grip strength values are obtained as 55.4 (± 8.16 kg) and 53.7 (± 5.81 kg), respectively. While the velocity values of the participants during the propulsive phase of BT exercise are obtained as 1.12 ± .22 m/s for MPV and 1.91 ± .29 m/s for PV, power values are obtained as 307.5 ± 62.6 W for MPP and 654.3 ± 122.1 W for PP.

**Table 1:** Participant's Some Physical and Anthropometric Characteristics

| Variables | n | Minimum | Maximum | Mean ± sd |
|---|---|---|---|---|
| Age (yr) | 13 | 20,0 | 32,0 | 25,4 (± 3,86) |
| Height (cm) | 13 | 171,0 | 197,0 | 187,5 (± 8,33) |
| Weight (kg) | 13 | 67,3 | 113,5 | 90,9 (± 14,8) |
| Muscle Mass (kg) | 13 | 34,2 | 54,9 | 44,3 (± 5,94) |
| Fat Mass (kg) | 13 | 5,90 | 31,1 | 14,1 (± 6,58) |
| Fat Mass (%) | 13 | 8,50 | 28,0 | 15,0 (± 4,79) |
| BMI (kg.m$^2$) | 13 | 19,3 | 31,9 | 25,8 (± 3,20) |

Table 3 shows the correlation analysis results between both right - left hand grip strength and $1RM_{BP}$ values with velocity and power parameters during the propulsive phase of BT exercise. According to the analysis results, it has been determined that there is a statistically positive and significant relation between both right and left hand gripping values of the participants and MPV ($r = .674$, $p < 0.05$; $r = .698$, $p < 0.01$, respectively) and PV ($r = .644$; $r = .670$, $p < 0.05$, respectively) values in BT exercise. No relation has been established statistically in terms of MPP ($r = .528$; $r = .456$, $p > 0.05$, respectively) and PP ($r = .487$; $r = .401$, $p > 0.05$, respectively) values. It has also been determined that there is a statistically positive and high level significant relation between $1RM_{BP}$ values of the subjects and MPV ($r = .728$), PV ($r = .775$), MPP ($r = .703$) and PP ($r = .759$) values obtained during the propulsive phase of BT exercise ($p < 0.01$).

**Table 2:** Participant's Upper-Body Strength Values and Variables during Propulsive Phase of Bench Throw Exercise

| Variables | n | Minimum | Maximum | Mean ± sd |
|---|---|---|---|---|
| Right-Hand Grip Strength (kg) | 13 | 41,9 | 66,3 | 55,4 (± 8,16) |
| Left-Hand Grip Strength (kg) | 13 | 45,9 | 62,2 | 53,7 (± 5,81) |
| $1RM_{BP}$ (kg) | 13 | 70,0 | 125,0 | 97,8 (± 15,0) |
| Load (kg) | 13 | 20,1 | 34,0 | 27,2 (± 4,45) |
| Time (ms) | 13 | 718,0 | 909,0 | 826,0 (± 48,2) |
| Displacement (cm) | 13 | 74,0 | 111,5 | 94,9 (± 10,7) |
| MPV (m/s) | 13 | ,74 | 1,61 | 1,12 (± ,22) |
| PV (m/s) | 13 | 1,22 | 2,40 | 1,91 (± ,29) |
| MPP (W) | 13 | 194,2 | 454,3 | 307,5 (± 62,6) |
| PP (W) | 13 | 447,5 | 918,6 | 654,3 (± 122,1) |

$1RM_{BP}$: one repetition maximal bench press; MPV: mean propulsive velocity; PV: peak velocity; MPP: mean propulsive power; PP: Peak power

## 4. Discussion

According to our knowledge, this is the first study investigating the relation between the velocity and power parameters during the propulsive phase of the bench throw exercise and the upper-body strength characteristics in handball players. Muscular force is an important factor in handball performance. Many researchers agree that upper-body muscular force yields a highly important advantage to the players in blocking, hitting, pushing and throwing (Fleck *et al.,* 1992; Bayios *et al,* 2001; Gorostiaga *et al.,* 2005, 2006; Marques and Gonzales-Badillo, 2006; Granados *et al,* 2007; Marques *et al.,* 2007; Chelly *et al.,* 2010). In this study, mean $1RM_{BP}$ values of the handball players have been found to be 97.8 (± 15.0 kg). In literature, while mean $1RM_{BP}$ values of elite handball players were found to be 68.8 (± 10.06 kg) in a study of Marques *et al.,* (2007); Debanne and Laffeya (2011) established that mean $1RM_{BP}$ values of handball players having a 2-year history of training at least were 73.3 (± 14.0 kg). It is surprising that $1RM_{BP}$ values are so low. In the study of Gorostiaga *et al.,* (2005), mean $1RM_{BP}$ values were found as 106.9 (± 11.6 kg) for elite players and 82.5 (±14.8 kg) for second league players. A similar result has been obtained by Granados *et al.,* (2007) in female handball players. In this abovementioned study, it has been determined that elite female handball players (47.9 ± 6.2 kg) have higher maximal strength values in BP exercise when compared to the amateur handball players (36.7 ± 4.6 kg). When it is considered that high upper body muscular force is an important prerequisite for handball performance, it isn't surprising that there is a significant difference between $1RM_{BP}$ values of elite and amateur handball players.

**Table 3:** Spearman Correlation Results between Participant's Upper Body Strength Values with Velocity and Power Parameters during Propulsive Phase of Bench Throw Exercise

| Variebles | | $HG_{Right}$ | $HG_{Left}$ | $1RM_{BP}$ | MPV | PV | MPP | PP |
|---|---|---|---|---|---|---|---|---|
| $HG_{Right}$ | r | | ,850** | ,753** | ,674* | ,644* | ,528 | ,487 |
| | p | | ,000 | ,003 | ,012 | ,018 | ,064 | ,091 |
| | n | | 13 | 13 | 13 | 13 | 13 | 13 |
| $HG_{Left}$ | r | | | ,582* | ,698** | ,670* | ,456 | ,401 |
| | p | | | ,037 | ,008 | ,012 | ,117 | ,174 |
| | n | | | 13 | 13 | 13 | 13 | 13 |
| $1RM_{BP}$ | r | | | | ,728** | ,775** | ,703** | ,759** |
| | p | | | | ,005 | ,002 | ,007 | ,003 |
| | n | | | | 13 | 13 | 13 | 13 |
| MPV | r | | | | | ,940** | ,714** | ,665* |

| | | | | |
|---|---|---|---|---|
| | p | ,000 | ,006 | ,013 |
| | n | 13 | 13 | 13 |
| PV | r | | ,571* | ,676* |
| | p | | ,041 | ,011 |
| | n | | 13 | 13 |
| MPP | r | | | ,830** |
| | p | | | ,000 |
| | n | | | 13 |

* $p < 0,05$; ** $p < 0,001$; $HG_{Rigth}$: Right hand grip strength; $HG_{Left}$: Left hand grip strength; $1RM_{BP}$: one repetition maximal bench press; MPV: mean propulsive velocity; PV: peak velocity; MPP: mean propulsive power; PP: Peak power

Muscular force is a highly important parameter in order to perform fast and successful movements like throwing with maximal effort (Newton and Kraemer, 1994). In literature, it is observed that the relation between different throwing techniques such as standing throw, basic throw or 3-step running throwing and one repetition maximal strength in BP exercise (Fleck *et al.,* 1992; Hoff and Almasbakk, 1995; Bayios *et al.,* 2001; Van Den Tillaar and Ettema, 2004; Gorostiaga *et al.,* 2005; Marques *et al.,* 2007; Granados *et al.,* 2007; Chelly *et al.,* 2010; Debanne and Laffaye, 2011) or the relation between lifting velocity in different weights in BP exercise and throwing velocity (Gorostiaga *et al.,* 1999; Marques *et al.,* 2007) has been investigated. In a study conducted by Can *et al.,* (2016) on the Turkish national wrestling athletes who had ranks in European and World Arm Wrestling Championships, it was obtained that there wasn't a statistically significant relationship between 1RMBP values with mean velocity, peak velocity and mean propulsive velocity attained during propulsive phases of bench throw (BT) exercises were applied by using an external load that corresponds to 30% of body weights of the participants. In the mentioned study, there was no statistically significant relationship between the velocity parameters of the BT exercise and 1RMBP, it was suggested that the participants had low 1RMBP values and that there was no propulsive motion exercises in the training programs because of the absence of propulsive motion in arm wrestling. However, there is no study analyzing the relation between velocity and power values during propulsive phase of BT exercise and $1RM_{BP}$ in handball players.. For this reason, the results obtained from the study are important for the literature of sports science. In this study, it has also been determined that there is a statistically positive and high level significant relation between $1RM_{BP}$ values of the participants and MPV ($r = .728$), PV ($r = .775$), MPP ($r = .703$) and PP ($r = .759$) values obtained during the propulsive phase of BT exercise ($p < 0.01$).

Similar results have been suggested in previous studies that examine the relations between the throwing performance of handball players and their upper-body strength indices. Marques *et al.,* (2007) have found that there is a positive ($r = .637$, $p = .014$) relation between maximal strength in BP exercise and throwing velocity. In this relevant study, it has been established that there are significant correlations between throwing velocity, maximal bar velocity at 26 kg and 36 kg ($r = .563$ and $r = .625$, $p < .04$, respectively) and maximal power at 36 kg and 46 kg ($r = .58$, $p < .03$). Gorostiaga *et al.,* (1999) have found a positive relation between standing throw velocity and bar speed during BP test in which 30% of 1RM is used in BP exercise for both elite and amateur handball players. It has also been suggested that elite handball players have high power output at the upper extremity. Debanne and Laffeya (2011) have stated that there is a strong correlation ($r = 0.55$) between $1RM_{BP}$ values of male handball players and their throwing velocities. Mean maximal power values of players have been found to be 675.1 (± +188 W). Joris *et al.,* (1985) have stated that one of the most important factors related to the arm throwing efficiency is lower and upper extremity muscular strength and power. In addition, physical characteristics of the athlete, technical skills and coordination of body segments are also among the important factors (Van-Muijen *et al.,* 1991).

Similar results have been achieved in female handball players. In the study of Hoff and Almasbakk (1995) conducted on female handball team players, it has been reported that there is a large relation ($r = .883$) between throwing velocity and $1RM_{BP}$ values. Granados *et al.,* (2007) have established that there is a positively significant relation between the standing throw velocities and $1RM_{BP}$ values of female handball players competing at elite and amateur level. In another study conducted by Granados *et al.,* (2013) on an international female handball team, it has been established that there is a statistically significant relation between the power values in 30% of 1RM in BP exercise and standing throw velocity and it has been alleged that this relation is more dependent on the ability of upper extremity to produce maximal power efficiency with submaximal loads during elbow extensional movement. The similar relation between power generation with upper-body parts and the ability to move lower loads at maximal velocities has been also reported by different authors for elite male handball players (Joris *et al.,* 1985; Fleck *et al.,* 1992; Gorostiaga *et al.,* 2005). However, such a relation hasn't been obtained in male handball players competing at a lower level (Gorostiaga *et al.,* 2005). In mentioned study, it has been stated that the reason for the lack of such a relation may be the coordinating capacity in the progression of the limb segmental movement from proximal to distal during low technique or throwing.

When the studies conducted in different sports branches are analyzed, a highly strong relation between punching velocity applied in different techniques and MPP in BT exercise has been obtained in the study of Loturco *et al.*, (2016) conducted on Brazilian national boxing team players and they have suggested that this relation confirms how important it is to develop their ability to apply a high strength at high velocities using the upper limb of the boxers. In another study conducted by Loturco *et al.,* (2014) on Brazilian national karate team players, a statistically significant relation has been obtained between upper and lower body throwing velocity and strength of the athletes and their power abilities and it has been uttered that this relation results from dynamic characters of throwing movement. In other words, the ability of the karate players to transfer a linear force momentum from the lower body to the upper body when the fists are punched is obligatory for them to hit their competitors as quickly as possible. Actually, this ability is related to the mechanical impulse directly created in a specific movement. In this regard, it has been suggested that the athletes who exert more force against the ground and move their body forward at a higher speed have achieved the best results in punching acceleration.

Hand grip strength that occurs after a compelling flexion of fist, wrist and all finger joints (Richards et al., 1996; Bohannon, 1997) with the maximal voluntary force exerted by the participant under normal biokinetic conditions by using the forearm and many muscles in the hand (Bassey and Harrie, 1993) plays an important role in determining the performance in many sports activities. The grip strength which is an important measure of overall health and accepted as one of the most valid clinical methods in the calculation of the strength (Hager-Ross and Schieber 2000) is often used as the indicator of general physical strength (Massey-Westrop et al., 2004) and hand and forearm muscle performance (Nwuga, 1975). That is to say, muscular force of the individual is evaluated (Foo, 2007). Grip strength is also important for catching and throwing the ball in different team sports (this is especially the case with regard to the dominant hand in handball) (Visnapuu and Jurimae, 2007; Fallahi and Jadidian, 2011). For this reason, it is widely accepted that grip strength measurements provide an objective index of functional integrity of the upper extremity (Balogun *et al*., 1991). It has also been suggested that height, weight and body mass index affect hand grip strength (Vila *et al.*, 2012).

In this study, hand grip strength values of handball players have been found to be 55.4 (± 8.16 kg) for the right hand and 53.7 (± 5.81 kg) for the left hand. It has been concluded that while there is a statistically positive and significant relation between the MPV ($r = ,674$, $p < 0.05$; $r = ,698$, $p < 0.01$, respectively) and PV values ($r = ,644$; $r = ,670$, $p < 0.05$, respectively) of the participants in BT exercises and both right and left hand grip strength values, there isn't any statistical relation in terms of the MPP ($r = ,528$; $r = ,456$, $p > 0.05$, respectively) and PP values ($r = ,487$; $r = ,401$, $p > 0.05$, respectively). In a study conducted by Can *et al.,* (2016) on the Turkish national wrestling athletes who had ranks in European and World Arm Wrestling Championships, it was obtained that there wasn't a statistically significant relationship between both left and right hand grip strength values with MPV and PV values during propulsive phases of the BT exercises were applied by using an external load that corresponds to 30% of body weights of the participants. These results are inconsistent with the results obtained with handballs in the present study. It can be suggest that that BT exercise is a pushing action and that it is usually caused by the pulling and gripping movements rather than the pushing motion of the players due to the nature of the wrestling sport. In the handball, the throwing action becomes very important in situations such as passing and shooting. In literature, in the study performed by Mikkelsen and Olesen (1976) on handball players, it has been reported that there is a significant relation between hand grip strength and throwing velocity. Similarly, in the studies conducted on elite water polo players (Ferragut *et al.*, 2011) and baseball pitchers (Pugh *et al.*, 2001), a significant relation has been obtained between the hand grip strength and throwing velocity. On the other hand, Van den Tillaar and Ettema (2004) have achieved a weak correlation ($r$ = .49, $P$ = .027) between isometric grip strength and throwing velocity of female handball team players.

Due to the fact that the arm-throwing motion becomes very important in situations such as throwing and passing in the handball and the upper limb muscle power and strength have a great influence on the throwing motion, it isn't surprising that there is a statistically significant relation between the hand grip and $1RM_{BP}$ strength values with velocity and power parameters during the propulsive phase of BT exercise in handball players. In conclusion, it can be suggested that upper-body strength characteristic affects velocity and power parameters positively, velocity and power characteristics are dominant and make an important contribution to the athletic performance and these results can yield benefit to the trainers and conditioners while preparing training programs in sports branches.

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