Mastergradsoppgave

# Effects of ballistic and maximal resistance training on throwing velocity in well-trained female handball players

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HØGSKOLEN I NORD-TRØNDELAG

# FULLMAKTSERKLÆRING – MASTERAVHANDLING

Norsk tittel: *Effekt av ballistisk og maksimal styrketrening på kasthastighet hos godt trente kvinnelige håndballspillere*

Engelsk tittel: *Effects of ballistic and maximal resistance training on throwing velocity in well-trained female handball players*

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**Effekt av ballistisk og maksimal styrketrening på kasthastighet hos godt trente kvinnelige håndballspillere**

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**Sammendrag:** Hensikten med dette studiet var å undersøke effekten av ballistisk og maksimal styrketrening på kasthastighet. Femten godt trente kvinnelige håndballspillere (18.5±1.3 år) meldte seg frivillig til å delta i studien. Et ni ukers pre- til post design ble valgt, og deltakerne ble parvis matchet i to grupper basert på prestasjon av pretest kasthastighet: maksimal treningsgruppe (MTG, n = 7) og ballistisk treningsgruppe (BTG, n = 8). Stående og tre-skritts tilløps kasthastighet ble testet før og etter en sju ukers trenings intervensjons periode. I tillegg, ble deltakerne testet i: (1) maksimal styrke i benkpress (1RM), (2) peak power, peak hastighet, tid til peak power og tid til peak hastighet i benkkast (40% av 1RM). Det viktigste funnet i dette studiet var at kasthastighet med tre-skritts tilløp for begge gruppene fikk en signifikant nedgang fra pre- til posttest (BTG: P = 0.005, MTG: P = 0.037), mens mindre nedgang ble registrert for det stående kastet. Et annet funn i dette studiet var at MTG økte signifikant mer i 1RM benkpress prestasjon enn BTG (P = 0.005). Begge gruppene økte peak power (BTG: P = 0.009, MTG: P = 0.007) og peak hastighet (BTG: P = 0.001, MTG: P = 0.014) signifikant i benkkastet, men ingen signifikant forskjell mellom gruppene ble observert. Konklusjonen var at begge gruppene reduserte prestasjonen i kasthastighet. Resultatet fra dette studiet kan gi utrykk for at ballistisk styrketrening ikke er bedre enn maksimal styrketrening for å øke kasthastighet.

**Nøkkelord:** Håndball, kasthastighet, power, ballistisk styrketrening, maksimal styrketrening

**Effects of ballistic and maximal resistance training on throwing velocity in well-trained female handball players**

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**Abstract:** The aim of this study was to investigate the effects of ballistic and maximal general resistance training upon throwing velocity. Fifteen well-trained female handball players (18.5±1.3 yr) volunteered to participate in the study. A nine week pre- to post design was chosen, and subjects were matched pair-wise into two groups based on pretest throwing velocity performance: maximal training group (MTG, n = 7) and ballistic training group (BTG, n = 8). Standing and three-step run-in throwing velocity was tested before and after a seven week training intervention period. In addition, subjects were tested for: (1)maximal strength in bench press (1RM), (2) peak power, peak velocity, time to peak power and time to peak velocity in the bench throw (40% of 1RM). The major finding of this study was that the three-step run-in throwing velocity significantly decreased for both groups from pre- to posttest (BTG: P = 0.005, MTG: P = 0.037), whereas a minor decrease were found for the standing throw. Another finding in this study was that MTG increased their 1RM bench press performance significantly as compared to the BTG (P = 0.005). Both groups increased their peak power (BTG: P = 0.009, MTG: P = 0.007) and peak velocity (BTG: P = 0.001, MTG: P = 0.014) significantly, but no significant difference was observed between groups. In conclusion, both groups impaired their throwing velocity performance. Results of this study may indicate that ballistic resistance training is not superior to maximal resistance training for increasing throwing velocity.

**Key words:** handball, throwing velocity, power, ballistic resistance training, maximal resistance training

# Introduction

Overarm throwing is considered as the most important aspect in many sports (Jöris et al. 1985; Van den Tillaar and Ettema, 2006; Wagner and Müller, 2008), and several researchers state that overarm throwing is one of the key skills necessary for success in team handball (Hoff and Almåsbakk, 1995; Van den Tillaar, 2003, 2004; Marques et al. 2007). Van den Tillaar and Ettema (2007) commented that the general kinematics of overarm throwing is comparable across disciplines (e.g. baseball, cricket, american football and handball). Overarm throwing is a complex motion (DeRenne, 2001), and can be defined as a fast discrete movement (Van den Tillaar, 2003; Van den Tillaar and Ettema, 2006, 2007). Generally, this implies that overarm throwing is of high intensity and short duration with a recognizable beginning and end of the movement. To emphasize that overarm throwing in handball is a fast movement, Van Muijen et al. (1991) states that a throw is completed between 0.3 and 0.4 seconds. The overarm throw is a discrete movement that can be divided into six phases: wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through (Van den Tillaar and Ettema, 2007). This kind of movement can also be referred to as an explosive or ballistic movement (Van den Tillaar, 2003). There are three main factors of importance for maximum velocity in a throw: Biomechanics, coordination of consecutive actions of body segments, and upper and lower extremity muscle strength and power (Marques et al. 2007). A fast, discrete complex movement such as throwing is depended of both proximal and distal coordination. Coordination is a result of different constrains, who can be divided into two groups: structural and functional (Van den Tillaar, 2003). Structural organismic constraints reflect body size parameters, and functional organismic constraint at a muscular level is the relationship between force and velocity. Bobbert and Van Soest (1994) states that both properties of the musculoskeletal system, and the control of this system, are important. This dissertation will mainly focus the musculoskeletal system and effects of this on throwing velocity.

A biomechanically study of DeRenne et al. (2001) on overarm throwing indicates that 47% of the velocity could be attributed to the stride and body rotation, whereas 53% of the velocity was due to action of the arm. Several researchers states that the main attributors for throwing velocity is maximal internal and external rotation velocity of the shoulder, and maximal elbow extension velocity, (Jöris et al. 1985; Van Muijen et al. 1991; Hoff and Almåsbakk, 1995; Zapartidis et al. 2007; Van den Tillaar and Ettema, 2007; Wagner and Müller, 2008). Van den Tillaar (2003) reported that 67% of ball velocity at ball release is due to these two factors. Hence, it could be suggested that resistance training program emphasizing increased overarm throwing velocity, should mainly include exercises on upper-body, especially on muscles in the shoulders and triceps brachii.

Many athletic performances are depended on the ability to produce high power in the movement (Pawlowski and Perrin, 1989; Hoff and Almåsbakk, 1995; Newton et al. 1996; Toji and Kaneko, 2004; MacIntosh et al. 2006:298; Gruber et al. 2007). This statement is accompanied by Fleck and Kraemer (2004:224) who pronounces that power is intimately related to sports tasks such as throwing a ball. Newton et al. (1996) declare that throwing requires a high power output of the involved muscles rather than a high force production. Power reflects the relationship between force, distance and time; hence, it is the function of force and velocity (Toji et al. 1997; Toji and Kaneko, 2004; Mangine et al. 2008). It has been reported that maximal power output occurs between 15-60% of 1RM in ballistic exercises (Mangine et al. 2008; Alemany et al. 2005), such as bench throw. In an overarm throw, power may be improved by adding more force, increasing the range of motion, or decreasing the time of the movement. Toji and Kaneko (2004) states that training protocols designed to improve muscle-power development must emphasize the strength or the velocity adaptations of muscle contraction.

Physical training entails exposing the organism to successive overloads (Åstrand et al. 2003:313), either as increased intensity, duration, or frequency. However, there are two different views on which overload are optimal to throw faster: overload force or overload velocity (Van Muijen, 1991; Van den Tillaar, 2003). First, there is training based on the principles of an overload of force, e.g. overweight balls or heavy resistance training. Second, there is training based on overload of velocity, e.g. underweight balls or explosive resistance training. These two training principles are derived from the paradigm of Hill, who shows the force-velocity curve of muscle contraction (Van den Tillaar, 2003; 2004). When the force is great, the velocity of muscle contraction is low, and when the velocity of a muscle contraction is high the force generated by the muscle is low. An increase of either force or velocity is expected to increase the power outcome of a movement. A study by Marques et al. (2007) indicated that throwing velocity where related to maximal dynamic strength, peak bar velocity and peak power in the bench press exercise. Furthermore, in addition to overload, specificity has also been highlighted as an important principle who should be adopted into any resistance training regimen with the intention of increasing performance (Van Muijen et al. 1991, Åstrand et al. 2003:313).

Several investigators have found a significant relationship between different resistance training regimens and throwing velocity in both baseball and handball (Van Muijen et al. 1991; Barata, 1992; Newton and McEvoy, 1994; Hoff and Almåsbakk, 1995; DeRenne et al. 2001; Van Den Tillaar, 2004; Wagner and Müller, 2008). The relationship between resistance training and pitching in baseball is extensively studied (DeRenne et al. 1985; 2001), but for overarm throwing in team handball there is limited and ambiguous information (Van Muijen et al. 1991; Hoff and Almåsbakk, 1995; Van den Tillaar, 2004; Van den Tillaar and Ettema, 2007; Marques et al. 2007; Ettema et al. 2008). Van den Tillaar, in his 2003 review article, discovered only one study (i.e. Hoff and Almåsbakk, 1995) conducted on general resistance training and throwing velocity in team handball. Hoff and Almåsbakk (1995) showed that a 10 week training regime of maximal bench press with 85% of 1RM (3×5-6 reps), had a significant increase on throwing velocity in female handball players. However, it should be mentioned that the control group also had a significant increase in throwing velocity, without any additional resistance training. Training with 85% of maximal load have been reported to have a close relationship with maximal dynamic strength (Åstrand et al. 2003:329; Fleck and Kraemer, 2004:6; Hatfield et al. 2006; Mangine et al. 2008). These results can indicate that overload of force (i.e. resistance training for maximal dynamic strength) should be one factor integrated as a part of a resistance training protocol for developing throwing velocity.

Another factor for enhancing throwing velocity would be training with overload of velocity, i.e. explosive or ballistic resistance training or also called power training. Maximal power output is produced at intermediate loadings and velocities; this is due to the previous explained force-velocity aspect in power development. In a traditional explosive repetition, the main target is movement velocity, but Newton et al. (1996) showed that power decreased during the last 50% of the range of motion. This statement is accompanied by Kraemer et al (1998) that demonstrated that in a bench press exercise power output was not maximal over about 50% of the range of motion with a 30% of 1RM loading. This phenomenon can be explained by a deceleration phase prior to achieving zero velocity at the end of the concentric phase. Ballistic training avoid the deceleration problem because the bar is thrown in the air, this gives a different power development spectrum. Ballistic resistance training (i.e. bench throw) has been mentioned as a more optimal velocity specific method than standard explosive resistance training in some exercises, e.g. bench press (Fleck and Kraemer, 2004:225; Gruber et al. 2007; Mangine et al. 2008). At some point is ballistic resistance training comparable to a handball throw, because a projectile is released at the en of the range of motion.

The main purpose of this study was to investigate the effects of two types of general resistance training on overarm throwing velocity. The hypothesis was that ballistic resistance training (i.e. power training) would be more optimal than maximal resistance training for developing overarm throwing velocity in female handball players.

## Methods

### Experimental design

To address the hypothesis of this study, a nine week pre- to post design was chosen. The participants (N = 15) was matched pair wise into two groups: Maximal training group (MTG, n = 7) and ballistic training group (BTG, n = 8). The group selection was based on throwing velocity in the pretest. Strength, power, velocity and handball throwing assessments were performed before and after the intervention period to evaluate the effects of two different resistance training programs on handball throwing velocity. Moreover, an additionally re-test on throwing velocity was performed one week after the posttest. This was done in order to explore a potential delay in performance due to several weeks of heavy training load.

### Subjects

Fifteen female experienced handball players, aged 17-20 years old, volunteered to participate in the study. Baseline characteristics of the subjects and training groups are given in table 1. The experiment was carried out in the end of the competitive season. Nine of the subjects play in the regional Norwegian under 18 handball league, five plays at the third highest level for seniors and twelve of the participants plays both leagues. All subjects were well-trained and had general resistance training experience for approximately one year. None of the participants had any experience with either maximal or ballistic strength training regimens.

**Table 1 -** Baseline characteristics of the subjects and training groups (mean±SD)

| Variables | Total (n=15) | MTG (n=7) | BTG (n=8) |
|---|---|---|---|
| Age (yrs) | 18.5±1.3 | 18.3±1.5 | 18.8±1.2 |
| Height (cm) | 173.0±6.0 | 174.6±4.6 | 171.8±7.1 |
| Body mass (kg) | 68.6±10.0 | 72.2±12.1 | 65.4±7.0 |
| Handball experience (seasons) | 9.9±3.0 | 10.2±2.6 | 9.7±3.3 |
| Strength experience (yrs) | 2.7±1.2 | 2.6±0.9 | 2.7±1.4 |

Before commencing the experiment, all players had an examination by the team physiotherapist, and every participant with medical disorders that might limit full participation was excluded. Subjects were required to sign a participant agreement before entering the study, and the study was approved by the Regional Ethical Committee of Norway. None of the players were taking any supplements or substances who were expected to affect physical performance or hormonal balance during the study.

**Measurement of throwing performance**

Throwing velocity was measured by a Doppler-radar equipment (10, 525GHz) called Embla Training Center (ETC). The radar was approved after CE (EU) and FCC (US) regulations. The radar was placed behind the goal with a measurement zone of 2m x 6m x 1,5m (width x length x height). Maximum velocity of the ball was measured from the point where the ball left the players hand to the ball hit the radars target zone. Throwing velocity was measured during two conditions: The three step run-in throw and the standing throw. In both conditions the throws were measured from six meters, i.e. inside the measurement zone. A standard senior woman handball (IHF 2) was used (weight 325-375 g, circumference 54-56 cm). After a standardized warm-up procedure, the subjects were instructed to throw the ball as fast as possible towards the center of a standard handball goal 3m x 2m (width x height). In the standing throw, the participants were instructed to perform the throw with both feet in the ground during the action. The subjects were instructed to perform the three steps run in throw as they normally do in match conditions. In both throwing conditions, the ball had to be released when the front foot was positioned at the 6 meter mark. The best of three attempts in each throwing condition was used in further analyses. Participants had a rest interval of minimum three minutes between each trial. The participants were instructed to be moderately active, i.e. easy running, in the rest periods. All subjects were familiarized with the procedures before testing, and the test procedure was supervised by the team head coach.

**Measurement of strength**

1RM bench press was measured on a standard time of the day using a standardized warm-up and progression procedure. Subjects performed the 1RM bench press test using a free-weight barbell machine, with a standard twenty kilo weightlifting bar and free weights. The subject got no support during the lift, and they had to lift the bar from the machine to the starting position themselves. The repetition started with fully extended elbows and then they lowered the weights at an intermediate speed down to the chest. To minimize any countermovement effect i.e. the bar bouncing on the chest, participants were instructed to let the bar remain on the chest for a quick second before returning the bar to the starting position as fast as possible. The one-repetition maximum was invalid if the lower back were excessive arched from the bench, or if the buttocks were elevated from the bench. The lift was also invalid of the heels did not remain at the floor trough the movement, or if the participant did not achieve full elbow extension when returning the bar to the starting position. The subjects' best trial with a complete range of motion and approved technique was used in further statistical analyses.

**Measurement of power and velocity**

Power testing was carried out minimum 48 hours after the 1RM bench press test. Peak power was measured with a linear encoder apparatus connected to MuscleLab V8.0 Model 4010/4020e (Ergotest Technology A.S). This equipment was also used to measure peak velocity, time to peak velocity, and time to peak power. The selection of measurement points is illustrated in figure 1. Measurements were carried out with one-repetition bench throw at ~ 40% of 1RM after a standardized general and specific warm-up procedure. To calculate the 40% loading the results tested in 1RM bench press was used. The focus in the concentric part of the power test was maximum execution speed, that is, high action velocity. The same instructions as for the 1RM bench press test were used, except that the participants were instructed to throw the bar as far up in the air as possible. When the bar was leaving the participants hands the test leader was catching the bar. The bench throw with the highest measured peak power of three trials was used in further statistical analyses. Only the concentric phase of the bench throw was counted for in the analysis, i.e. from when the bar was steady at the chest of the subject, until the spotter was catching the bar.

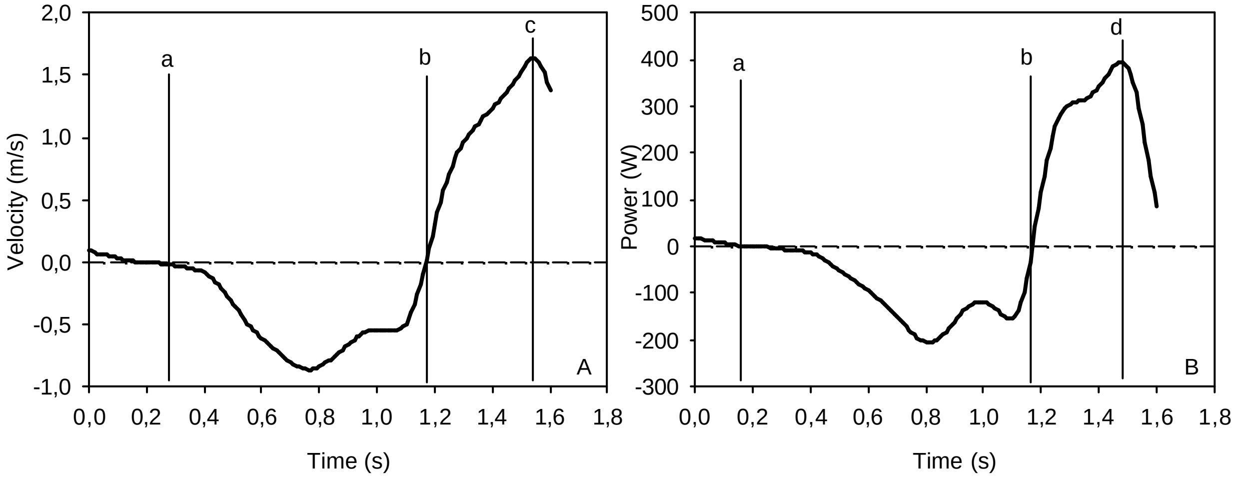


**Figure 1 -** Determination of peak velocity (A) and peak power (B) in the bench throw test. Line a: start of the eccentric phase. Line b: start of the concentric phase. Line c: point of peak velocity. Line d: point of peak power. Time to peak velocity is the time interval between line b and c. Time to peak power is the time interval between line b and d.

**Training procedure**

MTG and BTG were submitted to two different training programs of maximal nineteen workouts through the training period. Both groups had a recovery period of seven days between training week three and four. It was instructed that the participants should have a minimum 48 hour rest period between workouts. If illness occurred during the training period, the workouts were displaced so every participant should expect to carry out nineteen workouts through the training period.

The MTG protocol consisted of 3x5 repetitions using a training load approximately 85% of 1RM in three exercises: Barbell bench press, barbell triceps extensions and standing barbell shoulder press. Subjects in MTG were instructed to put on a load of 2.5 kilos every time they expected to exceed five repetitions in a set. During training, weights were either added or removed so that the subject always was able to just finish the required five repetitions. The BTG protocol used the same sets and repetitions as MTG with a training load of ~ 40% 1RM in the same three exercises. However, the BTG subjects were explicitly told to perform the exercises ballistic, i.e. throw the bars in the air as high as possible at the end of the movement. In both the bench throw and triceps extension throw in the BTG training regimen the participants depended of a spotter. Participants were instructed in spotting technique to insure the BTG subjects safety. In the standing barbell shoulder press BTG group were instructed to perform the concentric phase as explosive as possible. The rest of the body were assigned a general resistance program, no extra resistance training were conducted on chest, shoulder and triceps muscles.

### Statistical analysis

Statistical analyses were carried out with SPSS version 15.0 (SPSS inc. Chicago, IL). Results are presented as mean and SD unless otherwise stated. Conventional methods were used for the calculation of means and SD. Comparisons between groups were carried out with the independent samples *t*-test. Paired samples *t*-test was used to discover with-in group changes. Data were checked for normality by use of Shapiro-Wilks test. Statistical significance was accepted at the 5% level ($P < 0.05$). SigmaPlot version 10.0 (Systat software inc.) were used to conduct figures.

## Results

### Throwing velocity

For three-step run-in throwing velocity (Tab. 2, Fig. 2A) there was a significant decrease in both groups (BTG: $P = 0.005$, MTG: $P = 0.037$), but no significant difference between groups was discovered ($P = 0.76$). Also, there was a tendency for the MTG towards decreased standing throwing velocity ($P = 0.07$; Fig. 2B), but no such tendencies for the BTG ($P = 0.30$) or for differences between groups were found ($P = 0.77$).

**Table 2 -** Throwing velocity, 1RM, power and velocity variables pre- and posttest for MTG and BTG (mean±SD)

| Variables | BTG (n = 8) | | MTG (n = 7) | |
|---|---|---|---|---|
| | Pre | Post | Pre | Post |
| Standing throw (km/t) | 67.8±4.4 | 66.3±3.1 | 68.4±5.1 | 66.4±5.6 |
| 3-step run-in throw (km/t) | 72.8±5.3 | 69.6±4.0$^{\times\times}$ | 74.6±4.6 | 71.9±5.3$^{\times}$ |
| 1RM bench press (kg) | 43.8±6.7 | 45.3±6.3$^{\times}$ | 46.8±8.0 | 51.8±6.7**$^{\times\times\times}$ |
| Peak Power (W) | 432.5±68.0 | 463.7±69.1$^{\times\times}$ | 460.4±97.5 | 508.7±87.5$^{\times\times}$ |
| Peak Velocity (m/s) | 1.753±0.104 | 1.885±0.131$^{\times\times\times}$ | 1.740±0.158 | 1.896±0.160$^{\times}$ |
| TtPeak Power (s) | 0.315±0.053 | 0.298±0.036 | 0.304±0.047 | 0.260±0.048$^{\times\times}$ |
| TtPeak Velocity (s) | 0.398±0.066 | 0.367±0.040 | 0.390±0.037 | 0.359±0.016 |

* = Significant difference between groups from pre- to posttest; *$P < 0.05$, **$P < 0.01$.
$^{\times}$ = Significant with-in group change from pre- to posttest; $^{\times}P < 0.05$, $^{\times\times}P < 0.01$, $^{\times\times\times}P < 0.001$.

### Strength, power and velocity variables

Both groups significantly increased their 1RM bench press performance from pre- to posttest (BTG: P = 0.049, MTG: P = 0.001; Tab. 2 and Fig. 2C). The MTG increased their 1RM bench press performance significantly as compared to the BTG (P = 0.005). Both groups significantly increased peak power (BTG: P = 0.009, MTG: P = 0.007; Tab. 2 and Fig. 2D), and peak velocity performance in the bench throw (BTG: P = 0.001, MTG: P = 0.014; Tab. 2), but no difference between groups were revealed. Time to peak power decreased significant for MTG (P = 0.008; Tab. 2), no change was found for BTG. No significant change for time to peak power was found between groups.

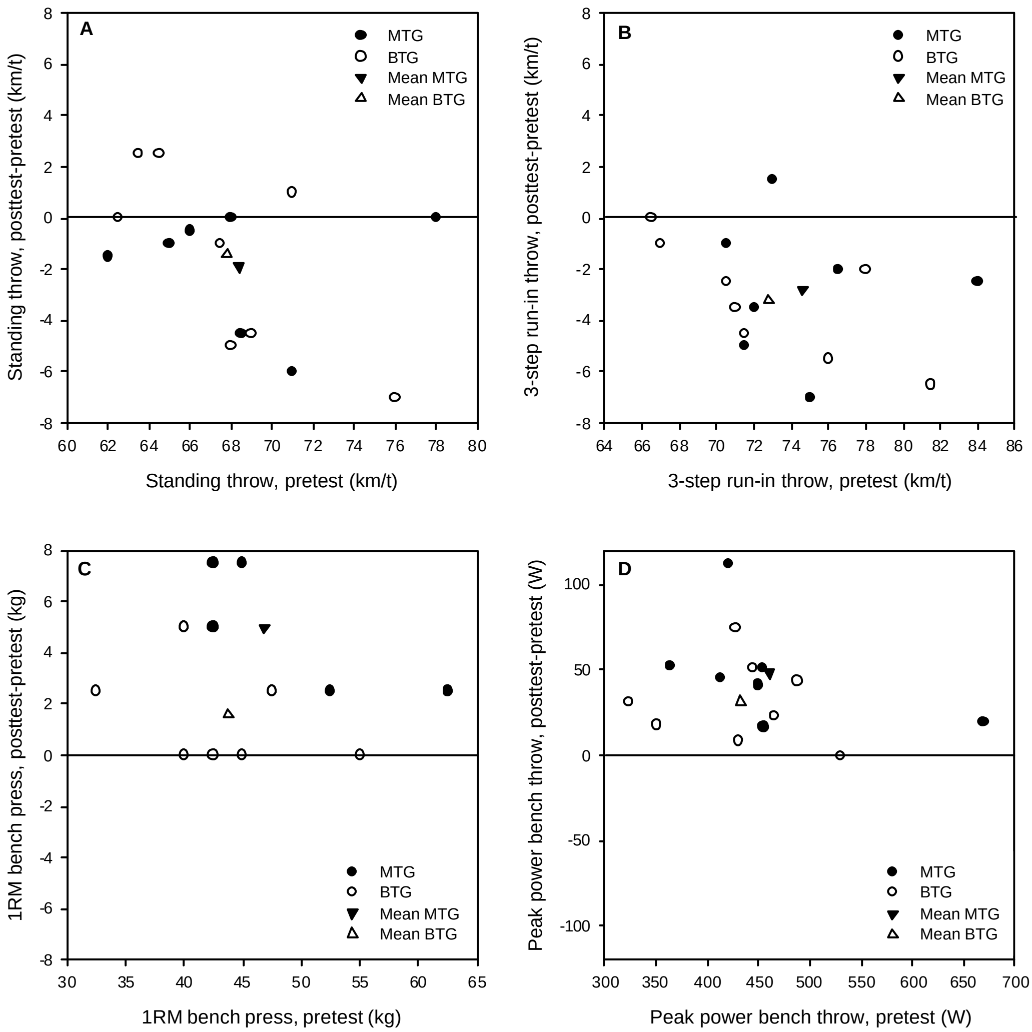


**Figure 2 -** Pretest and delta scores for (A) standing throw ($SD_{pooled}$ = 4.44), (B) three-step run-in throw ($SD_{pooled}$ = 4.91), (C) 1RM bench press ($SD_{pooled}$ = 7.23), and (D) peak power bench throw ($SD_{pooled}$ = 81.10) for 15 subjects during a seven week resistance training period. MTG = Maximal training group (n = 7), BTG = Ballistic training group (n = 8). Both groups significantly decreased their three-step run-in throw performance and increased their 1RM bench press performance from pre- to posttest. The MTG increased their 1RM bench press performance significantly more than the BTG.

## Discussion

In this study the effects of upper-body maximal and ballistic resistance training upon throwing velocity were examined in well-trained female handball players. The major finding of this study was that the three-step run-in throwing velocity significantly decreased in both groups, after the training intervention period.

### Throwing velocity

After the seven week training intervention period, both groups decreased equally and significantly by ~4% in three-step run-in throwing velocity. A similar tendency was also discovered in the standing throw with ~2.5% decrease, yet this reduction was not significant. These results are in conflict with a study of Hoff and Almåsbakk (1995), which revealed a significant increase in the three-step run-in throwing velocity (17%) for the training group, after a ten week maximal resistance bench press training period. However, it should be mentioned that their control group (regular throwing practice) also increased their three-step run-in throwing velocity with 9% (Hoff and Almåsbakk, 1995), yet a significant difference between groups were observed. Significant increases were also found in standing throwing velocity for both training and control group (18 and 15%, respectively), but no significant difference between groups was found. The severe increase in the study of Hoff and Almåsbakk (1995) can indicate that the participants were novices, with a considerably low pretraining condition. This statement can be supported by Van den Tillaar (2003) who pronounces that a subject improves much in the beginning of learning the task, while the rate of improvements (changes towards zero) declines considerably as practice continuous.

Experts have an optimized throwing technique, and such an optimized throwing pattern has not been established for novices (Van den Tillaar and Ettema, 2006). Therefore, regular throwing practice for beginners may lead to an improved coordination patterns, and great increase in throwing velocity. For this study, there was a lack of throwing practice due to: (1) season ending in mid-training period, (2) hard competition schedule, and (3) that the coach mainly prioritized tactical drills in the team practices. Small amounts of throwing practice may be a limiting factor for enhancing throwing velocity in this study, because the participants had a possible change in their functional organismic constrain through resistance training (e.g. an increase in maximal strength and power), but did not change the control of the system through regular throwing practice. Bobbert and Van Soest (1994) states in this relation that if muscles are strengthened while control remains unchanged, performance decreases rather than increases. Studies that discovered increased throwing velocity after an intervention period are mainly derived from training with light balls (Van Muijen, 1991; Barata, 1992; Van den Tillaar, 2004), which contain both neuromuscular adaptions and changes in control through actual throwing movement practice. Van den Tillaar (2003) states that the same coordination pattern in the throwing movement are observed in throwing with 0.2 kg ball as with 0.8 kg balls. These findings indicate that the high speed aspect in a throw movement may be more optimal than the low speed, according to muscle contractions. However, neither BTG nor MTG did profit of their resistance training at different contraction velocities due to throwing velocity incensement in the present study. It seems to be a limited transfer between both maximal and ballistic general upper-body exercises, and throwing velocity. It may be caused by the muscles involved during the throwing movement who changed their properties (organismic constraints), without updating the internal interaction between body segments. This argument can be a possible explanation of decreasing results in throwing velocity for both BTG and MTG in this study.

**Strength, power and velocity variables**

The main findings after seven weeks of resistance training was that MTG significantly increased their 1RM bench press performance more than BTG. However, the increase with-in the BTG was significantly. Both MTG and BTG significant increased peak power and peak velocity, there was no significant differences between groups. In addition, MTG decreased their time to peak power significantly, i.e. they reached peak power faster at posttest than at the pretest. This decrease in time to power is probably due to an increase in maximal strength.

The hypothesis of this study was that ballistic resistance training would benefit power development more than maximal resistance training, and that increased power development has a positive transfer to throwing velocity performance. Both groups significantly increased their peak power, without any change between groups. The increase in peak power for MTG was probably due to an increased maximal dynamic force (1RM bench press), as for BTG a significant increase in peak velocity may have been the contributing factor for peak power. As pointed out in the introduction, both force and velocity could influence the power development spectrum. One possible explanation of the lack in transfer from an increase in strength and power to throwing velocity is the exercise specificity. The three exercises used in this study was bench press, shoulder press and triceps extensions, and these exercises are primary performed linearly, where the bar is moved in a vertical manner up and down from the chest or shoulders. As for overarm throwing, internal and external rotation velocity is mentioned as one of the main predictors for throwing velocity. This may indicate that resistance training with rotations of the shoulder would benefit throwing velocity. A study of Ettema et al. (2008) showed that heavy specific resistance (pulley device) training does not show a stronger effect than training the performance exercise (1.6% and 6.1% increase, respectively). This may implicate that the transfer of the specific heavy resistance training effects to handball throwing can be assumed to be uninhibited.

## Conclusion

The results of this study indicate that a short period of resistance training have a negative effect on throwing velocity in well-trained female handball players. Results of this study may indicate that ballistic resistance training is not superior to heavy resistance training on throwing velocity.

## Acknowledgement

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