Serbian Journal of Sports Sciences
2014, 8(1): 33-40
UDC 796.322.012.2(481)

ISSN 1820-6301
ID 234519052

Original article
Received: 1 June 2013
Accepted: 15 Feb 2014

ASPECTS OF SHOOTING VELOCITY IN NORWEGIAN ELITE TEAM HANDBALL

Shaher A. I. Shalfawi[1,2], Stephen Seiler[3], Espen Tønnessen[2], Thomas A. Haugen[2,3]

[1]Norwegian School of Sports Sciences, Oslo, NORWAY.
[2]Norwegian Olympic Sports Center (Olympiatoppen), Oslo, NORVAY.
[3]University of Agder, Kristiansand, NORVAY.

Abstract The aim of this study was to quantify differences in shooting velocity as a function of player position, age, shooting type and shot placement on goal. Seventy-four male elite handball players (age 22 ±3 yrs, height 187 ±7 cm, body mass 86 ±10 kg) were recruited. The athletes performed set shots, low arm shots and jump shots with a 2 m run-up in randomized order, and all shots were monitored by a radar speed gun. The results show that back players had significantly higher ($p < 0.05$) ball shooting velocity of 2.1 ± 1.0 m•s^{-1} compared to pivots, 4.3 ± 0.7 m•s^{-1} compared to wing players, and 5.6 ± 0.9 m•s^{-1} compared to goalkeepers. Pivots, on the other hand, had significantly higher ($p < 0.05$) ball shooting velocity of 2.3 ± 1.0 m•s^{-1} compared to wing players, and 3.5 ± 1.2 m•s^{-1} compared to goalkeepers. Furthermore, ball shooting velocity was significantly different between players aged < 21 years (83.8 ± 7.3 m•s^{-1}) and players aged > 21 years (85.0 ± 5.8 m•s^{-1}). The results show that the set shot (86.8 ± 6.6 m•s^{-1}) and the low arm shot (85.8 ± 6.0 m•s^{-1}) had significantly higher velocity compared to jump shot (80.6 ± 5.5 m•s^{-1}). No differences in shooting velocity were detected regarding shot placement (high vs. low) on the goal for either type of shooting. This study provides effect magnitude estimates for the influence of playing position, age, shooting type and ball shot placement on shooting velocity in male handball. High performance players achieve greater shooting velocities regardless of type of shooting and shot placement on goal. The ability to use varying shooting strategies is crucial in handball.

Key words: Ball release velocity, physical demands, shooting ability

INTRODUCTION

Handball is one of the most popular team sports worldwide. According to the International Handball Federation, about 800 000 teams from 183 handball associations are registered [16]. In recent years, handball has received increased attention in research literature, and several authors have investigated the physical demands among elite players [9, 19, 22]. Performance in handball depends upon a variety of individual skills and the interaction among different players within the team. Although technical and tactical skills are considered to be predominant factors, physical capabilities must also be well developed in order for a player to become successful.

High throwing velocity and shooting precision are crucial performance factors in handball. Ball release velocity has been correlated to anthropometric variables such as body mass, lean body mass, height, body mass index, hand size, and arm span [5, 25]. A large number of studies have highlighted the importance of strength and power in both upper and lower extremities in order to achieve high throwing velocity [5, 8, 9, 10, 12, 13, 17, 23, 25]. Other authors have investigated the biomechanical aspects of throwing motions. The pattern of optimal throwing motion is characterized by a sequential action of body segments in order to attain maximum speed in the most distal segment of the system at the instant when the object is thrown [1, 18]. The ability to transfer momentum between the lower and the upper body during delivery is crucial for throwing velocity [20]. In handball overarm throws, the acceleration of the ball is primarily a result of internal shoulder rotation and elbow extension [6, 7, 25, 26, 30]. Wagner et al [30] emphasized the importance of a specific proximal-to-distal sequence, where higher velocity may be achieved with a delayed initiation of trunk flexion. Increased velocity can be attained by increasing the speed of the initial movement in order to provoke higher inertia forces [11].

Several aspects regarding throwing velocity in handball remain unclear or unknown. Some investigations have shown that players from higher competition levels achieve higher ball speed compared to players

from lower standards of play [2, 8, 24, 30]. However, Granados et al [10] reported no differences in throwing velocity among females of national and international playing standard. Vila et al [27] found no differences in ball speed across playing positions among female players when throwing on goal without a goalkeeper. When throwing with a goalkeeper, the back players showed higher values than wings and goalkeepers. No reputable studies have so far performed similar analyses of male players. Wagner et al [29] reported significantly higher ball release speed in overhead throws compared to side-arm throws, while Fleck et al [6] found that male players reach ~7% higher ball speed in set shots compared to jump shots. No studies have so far included set shots, jumps shots and under-arm shots in the same analysis. Furthermore, no studies have evaluated throwing velocity as a function of age or shot placement on goal. Therefore, the aim of this study was to quantify possible differences in throwing velocity as a function of the athlete's: 1) playing position, 2) age, 3) type of throw, and 4) shot placement on goal.

METHODS AND MATERIALS

EXPERIMENTAL APPROACH TO THE PROBLEM

Player positions were identified for each athlete by self-report as back players, pivots, wings and goalkeepers. Athletes' age was calculated from date of birth and testing date and categorized as < 22 or > 22 yrs. The rationale behind the age categorization was sample size distribution and equal split. During the test session, the athletes executed set shots, low arm shots and jump shots with a 2 m run-up either high or low on goal. The order of both throwing types and placements on goal was randomized. The test was completed when two successful attempts were captured for each type of throw (set shot low/high, low arm shot low/high, and jump shot low/high). If the specified shot was rejected, a new trial was performed until approved by the supervisor. Thus, all players executed at least 12 throws in total during the test session. Two successful attempts for each throw type per person were included for analyses.

SUBJECTS

In total, 74 male handball players (age 22±3 yrs, height 187±7 cm, body mass 86±10 kg) were recruited for the study (Table 1). Participants played for 8 different 1st division teams in the Norwegian Handball League for seniors. Some of the players played in the senior national team while several others were members of junior national teams of different age groups. Informed written consent was obtained in advance from each subject prior to participation. The study was performed in accordance with the Helsinki Declaration and was approved by the ethics committee of the Faculty for Health and Sport, University of Agder.

Table 1. Sample size, age, body mass, stature and body mass index (BMI) for the analyzed categories of players (Mean and SD)

Playing category	N	Age	Body mass	Body height	BMI
Back players	32	21 ± 1	86 ±8	188 ±5	24.4 ±2
Pivots	9	23 ± 4	99 ±12[A]	193 ±5[D]	26.5 ±2[E]
Wings	22	22 ± 2	79 ±4[B]	181 ±5[E]	24.1 ±1
Goalkeepers	11	23 ± 5	89 ±9	192 ±5[F]	24.3 ±2
< 22 yr	38	19 ± 1	84 ±10	186 ±7	24.2 ±2
> 22 yr	36	25 ± 3	88 ±9[C]	188 ±6	25.0 ±2[F]
All	74	22 ± 3	86 ±10	187 ±7	24.6 ±2

[A]Pivots > than back players (p<0.01), goalkeepers (p<0.05) and wings (p<0.01). [B]Wings < than the other position categories (p<0.01). [C]>22 yr more body mass than < 22 yr players (p<0.05). [D]Pivots and goalkeepers > other position categories (p<0.01). [E]Wings < other position categories (p<0.01). [F]Pivots > other playing position categories (p<0.05). [F]>22 yr players >BMI than <22 yr players (p<0.05).

PROCEDURES

All athletes completed the throwing velocity test between 8 and 11 am at the Norwegian Olympic Training Center in Oslo. All testing was performed in the off-season. Prior to the tests, all athletes performed a 20 min individual warm-up similar to their match procedures. This included jogging and handball throwing followed by shooting on goal with increasing intensity. Regarding nutrition, hydration, sleep and physical activity, the athletes were instructed to prepare themselves as they would for a regular game, including no high intensity training the last 2 days before testing.

For all shots during the test session, the ball was released from the 9 m line directly in front of the goal. There was approximately 1 min rest between each attempt in order to avoid fatigue effects. Set shots and

low arm shots were executed from the ground, while jump shots were executed from the air. In low arm shots, the ball had to be released below the horizontal level of the shoulder. This was controlled by test leader A. Shot placement on goal was categorized as high or low. The upper shooting zone was defined as the area between the upper bar of the goal and 80 cm below, marked by a plank attached to the side posts. The lower shooting zone was defined as the floor area between the goal line and 2 m in front, marked by a taped line. Test leader B decided whether the shots were inside or outside the specified zone.

A standard handball for men was used (mass 0.48 kg, circumference 58 cm). All throws were monitored by a radar speed gun (Bushnell Speedster, Overland Park, USA). Test leader C was positioned at the 9 m line and about 1 m to the right of the throwing athlete. The radar gun was pointed at the middle of the goal, and the elbows of the test leader were placed on a table for stability. According to the manufacturer, the radar provides instantaneous speed measurements to +/- 0.4 $m \cdot s^{-1}$ accuracy [3].

Statistical Analysis

All analyses were carried out using Predictive Analytics SoftWare (PASW) [21]. A histogram plot and Shapiro-Wilk's test revealed that none of the analyzed variables in this study followed a normal distribution within the groups. Therefore, the non-parametric Kruskal-Wallis test was used. In cases where differences were detected, a Mann-Whitney U post hoc test was assessed to determine the differing variables. The descriptive statistics were calculated and reported graphically with 95% confidence intervals (CI). Effect magnitude was interpreted categorically as small (d from 0.2 to 0.6), moderate (d from 0.6 to 1.2) or large (d from 1.2 to 2.0) using the scale presented by Hopkins et al [15]. Pearson correlation (Pearson's r) was computed to observe the relationships between throwing velocity and measures of physical characteristics of the participants. Furthermore, the two-way mixed Intra-class Correlation (ICC) reliability and the coefficient of variation (CV) between trails were calculated for all measures according to the guidelines provided by Hopkins [14]. The level of significance was set at $p \leq 0.05$ for all analysis.

RESULTS

The p value for all reliability measures was $p < 0.01$. In addition, the between-trial reliability for jump shot low at the goal was intraclass correlated, ICC = 0.76 with a CV of 3.4%; for the jump and shot high at the goal, ICC = 0.79 with a CV of 3.8%; for the set shot low at the goal, ICC = 0.84 with a CV of 3.6%; for the set shot high at the goal, ICC = 0.78 with a CV of 3.8%; for the low arm shot low at the goal, ICC = 0.71 with a CV of 4.2%; and for the low arm shot high at the goal, ICC = 0.84 with a CV of 3.2%.

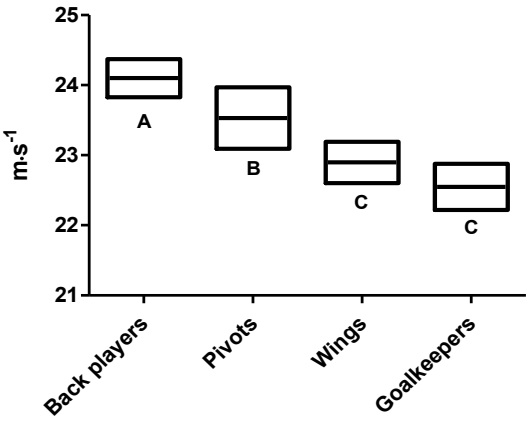

Figure 1. Mean and 95% confidence intervals for shooting velocity as a function of playing position. Statistical differences exist between boxes with different letters; no statistical differences exist between boxes with similar letters

The shooting velocity for all shooting types combined ± Standard deviation (SD) were 86.8 ± 6.8 $m \cdot s^{-1}$ for back players, 84.7 ± 5.8 $m \cdot s^{-1}$ for pivots, 82.4 ± 6.2 $m \cdot s^{-1}$ for wing players, and 81.2 ± 4.8 $m \cdot s^{-1}$ for goal keepers. Further analyses showed that back players had a significantly higher ($p<0.05$) ball shooting velocity of 2.1 ± 1.0 $m \cdot s^{-1}$ compared to pivots, 4.3 ± 0.7 $m \cdot s^{-1}$ compared to wing players, and 5.6 ± 0.9 $m \cdot s^{-1}$ compared to goalkeepers. On the other hand, pivots had a significantly higher ($p<0.05$) ball shooting velocity of 2.3 ± 1.0 $m \cdot s^{-1}$ compared to wing players, and 3.5 ± 1.2 $m \cdot s^{-1}$ compared to goalkeepers. No other differences were observed in shooting velocity across the players' positions (Figure 1).

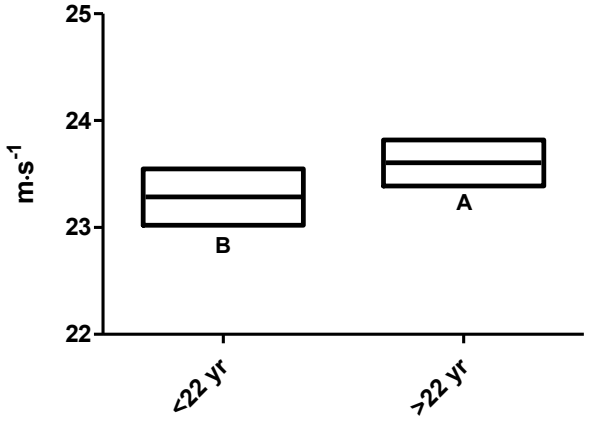

Figure 2. Mean and 95% confidence intervals for throwing velocity as a function of age. Statistical differences exist between boxes with different letters; no statistical differences exist between boxes with similar letters.

The ball shooting velocity was 83.8 ± 7.3 m•s^{-1} for the players aged less than 21 years old, and 85.0 ± 5.8 m•s^{-1} for the players aged over 21 years old (Figure 2). The results indicate that there was a statistically significant difference in shooting velocity between the age groups ($p<0.05$).

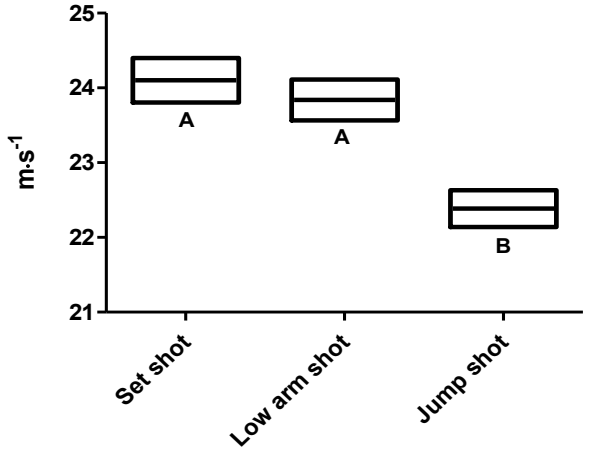

Figure 3. Mean and 95% confidence intervals for throwing velocity as a function of shooting type. Statistical differences exist between boxes with different letters; no statistical differences exist between boxes with similar letters

The results show that the participants' ball shooting velocity was 86.8 ± 6.6 m•s^{-1} for the set shot, 85.8 ± 6.0 m•s-1 for the low arm shot, and 80.6 ± 5.5 m•s^{-1} for the jump shot (Figure 3). Furthermore, participants had significantly higher shooting velocity in the set shot and low arm shot compared to the jump shot ($p<0.05$). No other differences were observed between shooting types.

The ball velocities for the jump shot low and high were 80.5 ± 5.0 m•s^{-1} and 80.7 ± 6.0 m•s^{-1}, respectively. For the set shot, the shooting velocities were 86.3 ± 6.8 m•s^{-1} and 87.2 ± 6.5 m•s^{-1} for shooting low and high, respectively. As for the low arm shot, the velocities for shooting low and high were 85.6 ± 6.0 m•s^{-1} and 86.1 ± 6.1 m•s^{-1}, respectively (Figure 4). The results did not show any significant difference in ball velocity between shooting high or low at the goal in any examined variables.

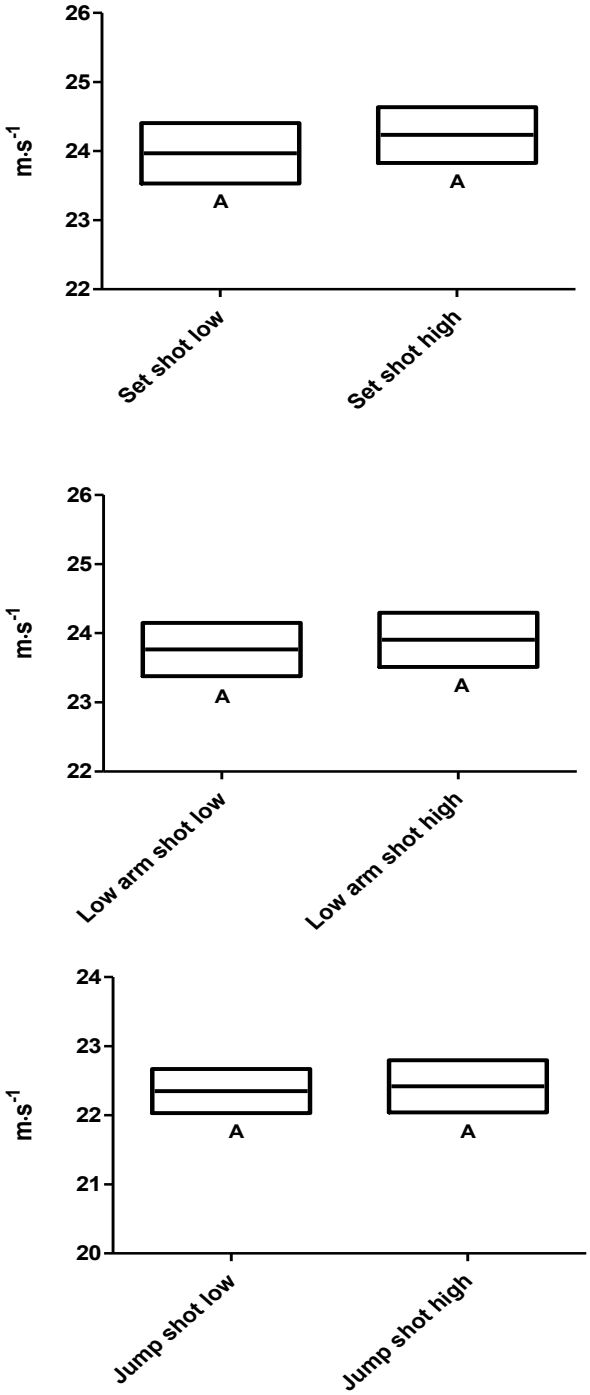

Figure 4. Mean and 95% confidence intervals for throwing velocity as a function of ball shot placement on goal. Statistical differences exist between boxes with different letters; no statistical differences exist between boxes with similar letters

Considering the relationship between physical characteristics of the players and their ball shooting velocities (Table 2), the results show a statistically significant relationship. However, further examination of Pearson r indicates that the relationship had a trivial to no effect on the players' shooting velocity.

Table 2. The relationship between physical characteristics and ball shooting velocity (Relationship presented as Pearson r)

Physical characteristics	Measures of physical characteristics	Relationship with ball velocity
Weight (Kg)	86.1 ± 9.8	0.13** (r^2 = 1.7 %)
Height (cm)	187.1 ± 6.5	0.11* (r^2 = 1.2 %)
BMI ($kg \cdot m^{-2}$)	24.6 ± 2.0	0.10* (r^2 = 1.0 %)
RPI ($cm \cdot kg^{-0.333}$)	42.4 ± 1.2	0.04 (r^2 = 0.2 %)

* = Significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$, r^2 = shared variance, RPI = Reciprocal Ponderal Index, BMI = body mass index

DISCUSSION

The data from the present study show that ball shooting velocity in male handball varied across playing positions. The back players' shooting velocity was higher compared to the other positions, and pivots shot the ball faster than wings and goalkeepers. The athletes in the > 22 yr age group achieved higher ball shooting velocities than the younger players by a trivial margin. Furthermore, set shots and low arm shots produced a higher ball speed compared to jump shots. However, vertical shot placement on goal did not seem to affect the ball speed. Even though we found a significant relationship between physical characteristics and shooting velocity, those general anthropometric measures have almost no predictive value for athletes´ maximal throwing velocity.

Between-trial reliability: The present results showed ICC values in the range 0.71 – 0.84 and CV in the range 3.2 – 3.8% for the analyzed throwing types. Our variability values had a somewhat higher variation compared to other studies where ICC values ranged between 0.95 – 0.99 and CV between 2.4 – 2.5% [4, 5, 23, 27]. We attributed the discrepancies to differences in testing protocols, as the other studies allowed the athletes to perform similar throwing types several times in a row before changing to another throwing type. The athletes in our study were instructed to change the throwing type continuously in order to avoid fatigue effects. It is reasonable to expect better throwing stability during similar repeated trials. However, compared to variability data of other physical capabilities in research literature, the present data are useful for further analysis.

Throwing velocity across playing positions: To our knowledge, this is the first study to quantify throwing velocity as a function of playing position in male handball. The results show that back players achieved higher ball speed than all other playing positions (Figure 1), and pivots achieved higher ball speed than wings and goalkeepers. Our results are in contrast to the findings by Vila et al [27], who found no positional differences when shooting on a goal without goalkeeper. However, when shooting with a goalkeeper, they reported higher throwing velocities among back players compared to wings and goalkeepers. Since no other studies have investigated the subject, we speculate that the rank of ball speed pattern across positions could be explained by training adaptation. It is reasonable to claim that set shots, low arm shots and jump shots with a two-meter run-up occur most frequently among back players; shooting velocity is crucial for back players as they execute most throws from a longer distance compared to pivots and wings.

Throwing velocity across age categories: No studies have so far examined shooting velocity across different age ranges in male handball players. Our results showed that players older than 22 years achieved higher ball speed compared to younger players. Even though the difference was significant, the magnitude was trivial compared to other studies where the magnitude of speed differences was reported to be large to very large among professional or elite players versus amateurs or lower division players [2, 8, 26, 30]. However, no such differences were revealed between female players of international and national standard [10]. While ball speed differences are pronounced among groups of heterogeneous performance levels, this relationship is not clearly present among players with more homogeneous standards of play. Theoretically, the trivial ball speed differences observed between the age categories could be due to poor training strategies and development of players in male Norwegian handball. However, the mean set shot velocity values (~24 $m \cdot s^{-1}$) achieved by the present athletes were equal to those of Tunisian, German, Austrian and Spanish elite players, where group mean values in the range 23-25 $m \cdot s^{-1}$ have been reported [4, 8, 28, 30]. Even though velocity comparisons across studies are further complicated by varying measuring methods (radar gun, electronic photo cells, motion capture systems or photogrammetry) and sample sizes, we do not believe that maximal ball speed is a performance limiting factor in Norwegian handball. The development of shooting velocity from junior to senior levels requires more research before further conclusions can be made.

Ball speed across throwing types: Our results show that male handball players achieved 6–8% higher ball velocity during set shots and low arm shots compared to jump shots, while no differences were observed between set shots and low arm shots. Wagner et al [29] compared above throws (set shots) with

side throws and reported 6% higher ball speed in above throws. Fleck et al [6] observed 6% lower throwing velocities for jump shots compared to set shots, which is in accordance to the present findings. In set shots, the athletes are in contact with the floor, allowing them to transfer forces from the lower extremity muscles to the upper body and arm. During jump shots, the forces can mainly be generated by the throwing arm. Furthermore, no previous studies have compared low arm shots with set shots or jump shots. We are somewhat surprised by the relatively small differences in ball speed across the different throwing types. Our results indicate that handball players mostly rely on force production by the arm, not the lower body, during shots executed from the ground. Vila et al [27] found that female elite handball players increased their ball speed in over arm throws by only 8–9% with a 3-step run-up compared to standing throws. Unlike athletes in athletic throwing events, handball players do not use an optimal throwing technique in order to achieve maximal ball speed. Van den Tillaar & Ettema [26] suggested that the role of the trunk and lower limb are of minor importance for handball players. Wagner et al [29] postulated that the advantage of shooting with different arm positions compensates for the disadvantage of reduced ball speed. Players use varying strategies in order to feint the goalkeeper or defending opponents so that they do not react in time to block the shots. An optimal throwing motion for maximal ball speed involves a run-up, front foot plant and a sequential action of body segments in order to attain maximum speed in the most distal segment of the system [1, 18]. In team handball, such a long preparation phase before ball release is easy to predict and thereby block or defend. However, in certain game situations, the players might benefit by better utilizing forces from the lower extremities. It should be useful to possess an optimal throwing motion for maximum ball speed, even though such actions occur less frequently during matches.

Throwing velocity as a function of shot placement on goal: No differences were detected regarding shooting high or low on goal for either of the shooting types. This shows that projection angle differences in the range 10°–15° do not affect ball speed towards the goal. Thus, handball players can place their shots on goal without considering any negative throwing velocity effects. In other throw-based sports (e.g. javelin), the projection angle is a crucial performance factor [1]. However, it is important to distinguish the aims of the different sports, e.g. distance vs. velocity.

The relationships between physical characteristics and shooting velocity: In this study, the players' body mass, body height and BMI were all significantly correlated with throwing velocity. However, the magnitude of the correlations was negligible, as the coefficient of determination was less than 2% for all analyzed variables. Thus, the observed differences in throwing velocity across the playing positions and age categories could not be explained by the athletes' body mass, body height or BMI. Our findings are in contrast to those reported by Debanne & Laffaye [5], who reported correlation values in the range 0.55–0.7 for the same variables among French 3rd, 6th and 9th division players. We attribute the discrepancies to varying ranges of playing standard, as the sample in our study was much more homogeneous compared to the study by Debanne & Laffaye [5]. Van den Tillaar & Ettema [24] concluded that fat-free body mass was a better measure for predicting throwing velocity.

CONCLUSION & PRACTICAL APPLICATIONS

This study provides effect magnitude estimates for the influence of playing position, age, throwing type and ball shot placement on shooting velocity in elite male handball players. Highly performing players achieved greater throwing velocities regardless of throwing type and shot placement on goal. The ability to use varying shooting strategies seemed to be a crucial performance factor. The differences in throwing velocity across playing positions were explained by neither body length nor body mass. Handball practitioners should therefore explore possible training methods in order to improve the athletes` throwing skills. Physical capabilities such as strength, power and throwing technique should be prioritized in the physical conditioning of players.

REFERENCES

1. Atwater, A. E. (1979). Biomechanics of overarm throwing movements and of throwing injuries. *Exercise and Sport Sciences Reviews*, 7, 43-85.
2. Bayios, I. A., Anastasopoulou, E. M., Sioudris, D. S., & Boudolos, K. D. (2001). Relationship between isokinetic strength of the internal and external shoulder rotators and ball velocity in team handball. *Journal of Sports Medicine and Physical Fitness*, 41 (2), 229-235.
3. Bushnell. (2012). *Bushnell Speedster*. Retrieved April 9th, 2013, from http://www.bushnellspeedster.com/
4. Chelly, M. S., Hermassi, S., & Shephard, R. J. (2010). Relationships between power and strength of the upper and lower limb muscles and throwing velocity in male handball players. *The Journal of Strength and Conditioning Research*, 24 (6), 1480-1487.
5. Debanne, T., & Laffaye, G. (2011). Predicting the throwing velocity of the ball in handball with anthropometric variables and isotonic tests. *Journal of Sports Sciences*, 29 (7), 705-713.
6. Fleck, S. J., Smith, S. L., Craib, M. W., Denahan, T., Snow, R. E., & Mitchell, M. L. (1992). Upper Extremity Isokinetic Torque and Throwing Velocity in Team Handball. *The Journal of Strength and Conditioning Research*, 6 (2), 120-124.
7. Fradet, L., Botcazou, M., Durocher, C., Cretual, A., Multon, F., Prioux, J., & Delamarche, P. (2004). Do handball throws always exhibit a proximal-to-distal

segmental sequence? *Journal of Sports Sciences*, 22 (5), 439-447.
8. Gorostiaga, E. M., Granados, C., Ibanez, J., & Izquierdo, M. (2005). Differences in physical fitness and throwing velocity among elite and amateur male handball players. *International Journal of Sports Medicine*, 26 (3), 225-232.
9. Granados, C., Izquierdo, M., Ibanez, J., Ruesta, M., & Gorostiaga, E. M. (2008). Effects of an entire season on physical fitness in elite female handball players. *Medicine and Science in Sports and Exercise*, 40 (2), 351-361.
10. Granados, C., Izquierdo, M., Ibanez, J., Ruesta, M., & Gorostiaga, E. M. (2013). Are there any differences in physical fitness and throwing velocity between national and international elite female handball players? *The Journal of Strength and Conditioning Research*, 27 (3), 723-732.
11. Grezios, A. K., Gissis, I. T., Sotiropoulos, A. A., Nikolaidis, D. V., & Souglis, A. G. (2006). Muscle-contraction properties in overarm throwing movements. *The Journal of Strength and Conditioning Research*, 20 (1), 117-123.
12. Hermassi, S., Chelly, M. S., Fathloun, M., & Shephard, R. J. (2010). The effect of heavy- vs. moderate-load training on the development of strength, power, and throwing ball velocity in male handball players. *The Journal of Strength and Conditioning Research*, 24 (9), 2408-2418.
13. Hoff, J., & Almåsbakk, B. (1995). The effects of maximum strength training on throwing velocity and muscle strength in female team-handball players. *The Journal of Strength and Conditioning Research*, 9 (4), 255-258.
14. Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Medicine*, 30 (1), 1-15.
15. Hopkins, W. G., Hawley, J. A., & Burke, L. M. (1999). Design and analysis of research on sport performance enhancement. *Medicine and Science in Sports and Exercise*, 31 (3), 472-485.
16. IHF. (2013). *History of the International Handball Federation*. Retrieved April 9th, 2013, from http://www.ihf.info/TheIHF/Profile/tabid/74/Default.aspx
17. Marques, M. C., van den Tilaar, R., Vescovi, J. D., & Gonzalez-Badillo, J. J. (2007). Relationship between throwing velocity, muscle power, and bar velocity during bench press in elite handball players. *International Journal of Sports Physiology and Performance*, 2 (4), 414-422.
18. Menzel, H. J. (1987). Transmission of partial momenta in javelin throw. In *Johnsson, B. (Ed.), Biomechanics X-8* (pp. 643 - 647). Champaign, IL: Human Kinetics.
19. Michalsik, L. B., Aagaard, P., & Madsen, K. (2012). Locomotion characteristics and match-induced impairments in physical performance in male elite team handball players. *International Journal of Sports Medicine,* 34 (7), 590-599.
20. Morriss, C., & Bartlett, R. (1996). Biomechanical factors critical for performance in the men's javelin throw. *Sports Medicine*, 21 (6), 438-446.
21. PASW. (2009). *Statistical Package for the Social Sciences (SPSS)*. Retrieved April 9th, 2013, from http:\\www.spss.com.hk
22. Povoas, S. C., Seabra, A. F., Ascensao, A. A., Magalhaes, J., Soares, J. M., & Rebelo, A. N. (2012). Physical and physiological demands of elite team handball. *The Journal of Strength and Conditioning Research*, 26 (12), 3365-3375.
23. Saeterbakken, A. H., van den Tillaar, R., & Seiler, S. (2011). Effect of core stability training on throwing velocity in female handball players. *The Journal of Strength and Conditioning Research*, 25 (3), 712-718.
24. van den Tillaar, R. (2004). Effect of different training programs on the velocity of overarm throwing: a brief review. *The Journal of Strength and Conditioning Research*, 18 (2), 388-396.
25. van den Tillaar, R., & Ettema, G. (2004). Effect of body size and gender in overarm throwing performance. *European Journal of Applied Physiology*, 91 (4), 413-418.
26. van den Tillaar, R., & Ettema, G. (2007). A three-dimensional analysis of overarm throwing in experienced handball players. *Journal of Applied Biomechanics*, 23 (1), 12-19.
27. Vila, H., Manchado, C., Rodriguez, N., Abraldes, J. A., Alcaraz, P. E., & Ferragut, C. (2012). Anthropometric profile, vertical jump, and throwing velocity in elite female handball players by playing positions. *The Journal of Strength and Conditioning Research*, 26 (8), 2146-2155.
28. Wagner, H., Buchecker, M., von Duvillard, S., & Muller, E. (2010[a]). Kinematic description of elite vs. low level players in team-handball jump throw. *Journal of Sports Science and Medicine*, 3, 15 - 23.
29. Wagner, H., Buchecker, M., von Duvillard, S. P., & Muller, E. (2010[b]). Kinematic comparison of team handball throwing with two different arm positions. *International Journal of Sports Physiology and Performance*, 5 (4), 469-483.
30. Wagner, H., Pfusterschmied, J., Von Duvillard, S. P., & Muller, E. (2012). Skill-dependent proximal-to-distal sequence in team-handball throwing. *Journal of Sports Sciences*, 30 (1), 21-29.

Address for correspondence:

Shaher A. I. Shalfawi
Norwegian School of Sport Sciences
Department of Physical Performance
Postboks 4014 Ullevål Stadion
0806 Oslo
NORWAY
Tel. +47 45 66 06 60
Fax. +47 22 23 42 20
E-mail: shaher.shalfawi@me.com