



## Frequent Immediate Knowledge of Results Enhances the Increase of Throwing Velocity in Overarm Handball Performance

by

Igor Štirn<sup>1</sup>, Jamie Carruthers<sup>2</sup>, Marko Šibila<sup>1</sup>, Primož Pori<sup>1</sup>

*In the present study, the effect of frequent, immediate, augmented feedback on the increase of throwing velocity was investigated. An increase of throwing velocity of a handball set shot when knowledge of results was provided or not provided during training was compared. Fifty female and seventy-three male physical education students were assigned randomly to the experimental or control group. All participants performed two series of ten set shots with maximal effort twice a week for six weeks. The experimental group received information regarding throwing velocity measured by a radar gun immediately after every shot, whereas the control group did not receive any feedback. Measurements of maximal throwing velocity of an ordinary handball and a heavy ball were performed, before and after the training period and compared. Participants who received feedback on results attained almost a four times greater relative increase of the velocity of the normal ball (size 2) as compared to the same intervention when feedback was not provided ( $8.1 \pm 3.6$  vs.  $2.7 \pm 2.9\%$ ). The velocity increases were smaller, but still significant between the groups for throws using the heavy ball ( $5.1 \pm 4.2$  and  $2.5 \pm 5.8$  for the experimental and control group, respectively). Apart from the experimental group throwing the normal ball, no differences in velocity change for gender were obtained. The results confirmed that training oriented towards an increase in throwing velocity became significantly more effective when frequent knowledge of results was provided.*

**Key words:** overarm throw, augmented feedback, team handball, set shot, ball velocity.

### Introduction

Maximal ball release velocity is a crucial variable for successful performance in many sport games such as team handball, baseball, soccer and water polo (van den Tillaar and Ettema, 2003). The velocity of the ball in an overarm throw depends on optimal throwing mechanics and body segments' characteristics. The overarm throw is determined by a proximal-to-distal principle (Calabrese, 2013; Putnam, 1993; Wagner et al., 2012; Weber et al., 2014) which describes progressive contribution of body segments to the momentum of the throwing object, beginning from the base of support and progressing through

to the hand. This progression can be observed by monitoring peak angular velocities of the involved segments or by monitoring the activation of the muscles moving these segments (Escamilla and Andrews, 2009; Hancock and Hawkins, 1996; Hirashima et al., 2002; Kelly et al., 2002). In addition, it is evident that the delay of the activation of the distal muscles with respect to the proximal ones should be optimal – not too short and not too long; if the delay is shorter than optimal, there is less time available for the contraction of the proximal muscles which then do less work and vice versa (Alexander, 1991;

<sup>1</sup> - University of Ljubljana, Faculty of Sport, Slovenia.

<sup>2</sup> - Al Attar Clinic for Physical Medicine and Rehabilitation and Sports Medicine, Doha, Qatar.

Chowdhary and Challist, 1999). The stretch-shortening cycle (SSC) is another mechanism which can contribute to the final throw velocity (Greziros et al., 2006), as it enhances concentric muscle action due to recovery of elastic energy stored during preceding eccentric contraction and increased agonist muscle innervation as a result of the stretch reflex (Bosco et al., 1981).

There are indeed many factors contributing to the final velocity of the ball at release. To evaluate these factors different demanding and time consuming acquisition and analysis methods are required including kinematic and electromyography assessments. However, successful implementation of all complex mechanisms discussed would generally result in a high final velocity of the ball, conversely low velocities would imply that throwing mechanics were not optimal.

Due to its ballistic nature, an overarm throw is performed in a short space of time and is controlled based on an open-loop system, which is a feed forward process and has no feedback (Magill, 2011). Due to a time limitation, the motor program controlling the involved effectors (muscles) containing all the information needed to carry out the throw is generated in the brain prior to the throw; there is no time to continually register, evaluate and implement the information to control the movement while it is in the process. However, the subject can receive feedback information after the task has been executed. The natural part of it is sensory-perceptual information referred to as task-intrinsic feedback, while the velocity added on presents augmented feedback. Augmented feedback of the velocity of a ball can be provided by a radar gun after an overarm throw. The information given by the radar gun falls to the subcategory of the extrinsic feedback known as knowledge of results (KR), while the category where the information concerning the movement characteristics is given is known as knowledge of performance (KP). KP is commonly provided verbally by the teaching or coaching staff during regular training sessions or by video recordings of the performance being carried out and shown to athletes. KR provides information that a subject is unable to detect using his/her own sensory system about performing a throw and can therefore add it to intrinsic sensory feedback (Magill, 2011).

There has been a lack of research evaluating the effectiveness of improvement of the throwing velocity due to immediate KR. Knowing the velocity of the ball enables the thrower to consolidate the right sensory perceptual information and increases the chance that the thrower will qualitatively repeat the performance. Feedback also involves the motivational component, encouraging the subject to continue performing a skill at the highest possible level. Kermode and Carlton (1992) studied differences in the maximum throwing distances between the groups who received either KP about their throwing technique or KR about the throwing distance and they found that the KP group demonstrated better results.

The aim of this study was to determine whether training with instantly provided quantitative feedback information of the velocity of the ball after every throw (in addition to the usual knowledge of performance feedback provided by the teaching staff) would enhance the gain of velocity with respect to the same training intervention where no KR information was provided. In addition, the secondary aim was to examine how such training (throwing a normal ball) would affect the velocities of the heavy ball throws which present different sensory perceptual information for the thrower. Indeed, sensory perceptual information might change due to different external conditions (van den Tillaar and Ettema, 2011), such as different weight of the ball (the force and time conditions vary with respect to the normal ball).

## **Material and Methods**

In order to verify differences in the throwing velocity increase during a six week training period, 50 female and 73 male students were randomly assigned to two groups including the experimental group that received knowledge of their results (KR) and a control group that received no knowledge of the results (NoKR). All subjects performed 2 series of 10 set shots twice per week for six weeks. The KR group received feedback information about throwing velocity measured by a radar gun and displayed immediately after every shot, while the NoKR group did not receive any feedback. Throwing velocity measurements of a normal (NB) and heavy ball (HB) were performed pre- and post-

training to determine the increase in velocity. Dependent variables included final velocity of the normal and heavy ball with respect to their initial velocities as well as their relative change. Independent variables consisted of the different training regimens hypothesized to impact differently the dependent variables, training with and without frequently provided throwing velocity value after every shot. According to the results of this study, the coach might decide to implement external feedback information in the training program.

### **Participants**

Fifty female (age  $21.1 \pm 2.1$  years, body height  $165.4 \pm 6.2$  cm, body mass  $59.1 \pm 7.4$  kg) and seventy-three male (age  $21.4 \pm 2$  years, body height  $180.1 \pm 5.4$  cm, body mass  $77.8 \pm 7$  kg) students participated in the intervention, divided into groups of 15 to 20 students. Each subject was considered healthy and injury-free at the time of the study. The experiment was performed with the University of Ljubljana (Faculty of sport) ethics committee's approval; each subject was provided with a full explanation of the protocols and signed informed consent was received before the study commenced.

### **Procedures**

The experiment was conducted within regular practical education classes on theory and methodology of handball at the faculty of sport following a well-established program. Practical classes (groups) of students were divided by gender. Before the commencement of the experiment, basic information regarding handball in general and the overarm throw called the three step set shot was provided to all students during the first four week learning sessions (two sessions per week). After the introduction period, the participants were randomly assigned to the experimental (KR) or control (NoKR) group; the groups were also divided by gender. During the next twelve sessions (twice per week for six weeks), all participants first performed a standardised warm up and then executed two series of ten handball three step set shots with maximal effort. Subsequently, the participants continued with their regular handball lessons. The experimental group (KR) was provided with the quantitative feedback on the highest ball velocity measured with the radar gun after every shot which was shown immediately on the display

board, while the participants of the control group (NoKR) were not. All subjects were provided with verbal encouragement during their throws to perform them with maximal effort.

The initial measurements were carried out in the last session of the introduction period and final measurements after six weeks of training. Every participant performed two series of three handball three step set shots. Due to possible muscle potentiation effect, series were not randomly assigned; first series of three shots were performed with the dominant arm using a normal size handball (NB: the volume 0.54 m, weight 375 grams, size 2) and the second series with the dominant arm using a heavy ball (HB; weight 800 grams). Identical balls for male and female participants were used. The shots were executed with maximal effort in the direction of the radar gun (Stalker ATS Professional Sports, Applied Concepts, Inc., USA), which was placed behind an ordinary handball port, seven metres from the shooter at the height of 1.5 m. A rest period of 15 s was allowed between the shots. During pre- and post-training measurements, no KR was given to either group.

The highest ball velocity of every shot was measured and the highest of the three velocities was used for further analysis. The initial (pre) measurement velocities were labelled NB<sub>i</sub> and HB<sub>i</sub> for the throws with normal and heavy ball, respectively, and final (post) measurement velocities were labelled NB<sub>f</sub> and HB<sub>f</sub>.

### **Statistical analysis**

Statistical analysis was performed using SPSS software (version 21; SPSS Inc., Chicago, IL, USA). Analysis of covariance (ANCOVA) was used to verify the differences between the velocities of the ball measured after the intervention (training) between the feedback and no-feedback groups, setting the pre-training velocity as the covariate and the post-training velocity as the dependent variable. Pre- to post-test velocity change was also expressed in percentages and the differences in the changes were calculated executing the independent T-test. The alpha level for significance was set at 0.05.

### **Results**

Absolute values of the velocities of the ball measured pre- and post-training are shown in Table 1.

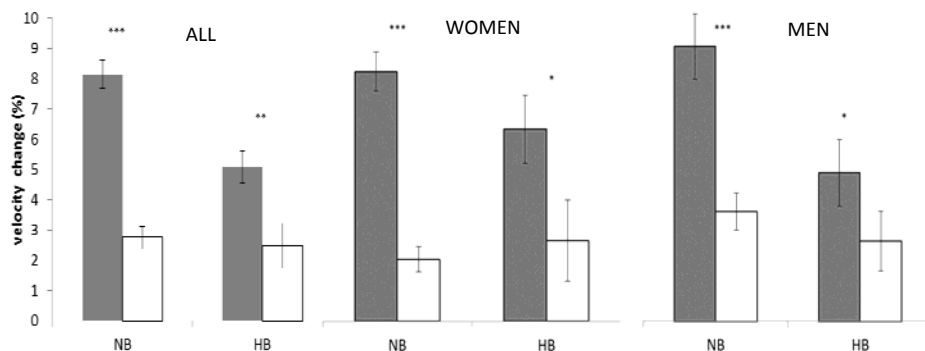
**Table 1**  
*Velocities of the ball (km/h) for KR and NoKR groups measured pre and post training for men and women*

KR GROUP – WOMEN						
				<i>Mean</i>	<i>s<sub>x</sub></i>	<i>SD</i>
	<i>N</i>	<i>Min</i>	<i>Max</i>			
NBi	24	48.8	78.0	61.2	1.6	7.9
NBf	24	50.8	81.1	65.8	1.6	8.0
HBi	24	34.8	56.6	45.0	1.3	6.5
HBf	24	35.0	66.7	47.7	1.5	7.4
NoKR GROUP WOMEN						
				<i>Mean</i>	<i>s<sub>x</sub></i>	<i>SD</i>
	<i>N</i>	<i>Min</i>	<i>Max</i>			
NBi	26	48.0	74.1	60.3	1.4	7.0
NBf	26	48.4	75.2	61.4	1.5	7.4
HBi	26	37.4	55.6	45.4	1.0	5.2
HBf	26	38.5	57.7	46.6	1.1	5.8
KR GROUP – MEN						
				<i>Mean</i>	<i>s<sub>x</sub></i>	<i>SD</i>
	<i>N</i>	<i>Min</i>	<i>Max</i>			
NBi	38	74.2	105.0	84.0	1.2	7.3
NBf	38	79.0	108.0	90.9	1.1	7.0
HBi	38	53.3	77.0	61.7	0.9	5.4
HBf	38	55.5	77.0	64.4	0.7	4.5
NoKR GROUP MEN						
				<i>Mean</i>	<i>s<sub>x</sub></i>	<i>SD</i>
	<i>N</i>	<i>Min</i>	<i>Max</i>			
NBi	35	68.2	102.2	83.0	1.4	8.3
NBf	35	68.0	111.0	85.8	1.5	8.6
HBi	35	48.6	78.5	61.9	1.0	5.8
HBf	35	50.0	80.0	63.3	0.9	5.4

*NB – normal ball, HB – heavy ball, i – initial (pre-test), f – final (post-test).*

**Table 2**  
 ANCOVA results for the effect of the intervention group (KR/NoKR) on post-test velocities after controlling for the initial throwing velocity for both normal and heavy ball shots

	F (NBi)	p	F (KR/NoKR)	p
ALL	$F_{1,122} = 3903.1$	.001	$F_{1,122} = 73.4$	.001
WOMEN	$F_{1,49} = 1346.4$	.001	$F_{1,49} = 73.0$	.001
MEN	$F_{1,72} = 458.2$	.001	$F_{1,49} = 39.8$	.001
	F (HBi)	p	F (KR/NoKR)	p
ALL	$F_{1,122} = 1806.3$	.001	$F_{1,122} = 9.8$	.002
WOMEN	$F_{1,49} = 271.0$	.001	$F_{1,49} = 4.7$	.035
MEN	$F_{1,72} = 272.1$	.001	$F_{1,49} = 5.7$	.020



**Figure 1**

Relative velocity changes for throws performed with a normal ball (NB) and a heavy ball (HB) for KR (full columns) and NoKR (empty columns) groups. Left – all participants, middle – women, right – men. \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ .

ANCOVA results are presented in Table 2 and showed a significant effect of the intervention group (KR/NoKR) on post-test velocities after controlling the initial throwing velocity for both normal and heavy ball shots. All effects irrespective of the gender and the ball used for testing (normal and heavy ball) were found to be significant ( $p < 0.001$  and  $p < 0.05$  for final

velocities of normal and heavy ball, respectively).

Relative changes of the velocity of the ball measured pre- and post-intervention with the significance of the t-test are shown in Figure 1. All changes were found significant for men and women separately as well as for all participants.

No significant effect for gender in relative changes for the KR group was found, (normal

ball,  $t(60) = -0.657$ ,  $p = 0.514$ ; heavy ball  $t(60) = 1.317$ ,  $p = 0.193$ ), as well as for the NoKR group for heavy ball throws ( $t(59) = 0.45$ ,  $p = 0.965$ ). However, for the NoKR group gender showed a significant effect for a normal ball relative to changes of velocity ( $t(56,4) = -2.060$ ,  $p = 0.044$ ); the relative changes of velocity were 3.3 and 1.9% for women and men, respectively.

## Discussion

The aim of the study was to examine if the information on the velocity of the ball at release, provided quantitatively immediately after each throw, could help the thrower to gain more velocity following a training period of six weeks as compared to the subjects who were not provided with such feedback. The results showed that 1) final velocity measured after six week training increased significantly in all groups; however, providing KR resulted in a greater relative increase of velocity of the ball with respect to the same intervention when KR was not provided; 2) the relative increase of velocity was larger when using a normal handball compared to the heavy ball.

In the present study, the training process was more effective when constantly confirmed and encouraged by KR. These results are consistent with previous research that have shown that precise quantitative KR is generally more effective for learning than qualitative KR (Bennett and Simmons, 1984; Magill and Wood, 1986; Reeve et al., 1990; Salmoni et al., 1983). However, some researchers suggest that giving augmented feedback after every performance is neither practical nor optimal for learning because it may overload attention capacity or may make the learner dependent on KR (Winstein and Schmidt, 1990). Therefore, to their conviction some type of relative or reduced frequency feedback may be more appropriate. Wulf et al. (1998) studied the influence of the KR frequency on learning the complex skill of skiing slalom and they observed that the group with 100% of KR achieved higher performance than the group provided with 50% KR. Moran et al. (2012) also indicated that tennis players could not accurately judge service speed without augmented feedback. However, when they were given KR their service performance increased following training. Keller et al. (2014) reported that the greatest long-term

drop jump height increase was achieved when participants were provided with 100% of augmented feedback, compared to 50% and 0%. They also found a significant within-session effect of augmented feedback, meaning that providing augmented feedback increased drop jump height immediately as well as long-term. Results of our study, therefore, confirm that KR could present a powerful tool for detecting the best trials of several similar performances, which can help the subject to direct the following actions and, consequently, gradually optimise his/hers throwing mechanics.

Another aspect of the discussion regarding KR concerns the time that lapses before feedback is given. Swinnen et al. (1990) formulated a hypothesis that there should be a minimum amount of time delay before KR was given; however, they found that providing KR too soon could interfere with task intrinsic feedback and, therefore, it should be delayed. Considering that in the present study, the use of a radar gun precluded the delayed display, the KR was provided to the subjects immediately after the shot and the options of providing the KR with a delay were not considered.

A normal ball was used during the training period, the differences in the velocity increase were also found when the heavy ball was thrown; however, the increase was much smaller compared to the normal ball. According to Schmidt and Wrisberg (2008), the programming process must include specifications such as particular muscles needed to produce the action, their precise order and level of activation, the relative timing and sequencing of the contractions and the duration of the respective contraction. Although these variables were not measured, previous research had shown that some of these specifications changed when throwing a heavy ball, especially the level of muscle activation and kinematics of the major contributors to overarm throwing: elbow extension and internal rotation of the shoulder (van den Tillaar and Ettema, 2011). Conversely, the muscles involved, sequencing of their activation and relative timing might be similar; hence, the reason why training with a normal ball had some effect on the velocity of throwing the heavy ball, although this effect was noticeably smaller compared to the increase in velocity of a normal ball throw. Perhaps this

finding can support the generalised motor programme theory of motor learning, which states that a pattern of movement rather than specific movement is programmed and can, therefore, be flexible to meet some altered environmental demands (Schmidt and Wrisberg, 2008).

The influence of feedback depends on the skill and the performer (Magill, 2011). Perhaps this is the cue for understanding the differences obtained in the amount of the velocity increase between males and females. Nevertheless, all the subjects that volunteered to participate in the research were given the same treatment and amount of encouragement. It could be possible that the males showed more enthusiasm or/and competitiveness during the training period and, therefore, the increase in velocity was higher. This was observed in the NoKR group, where differences between genders were found to be significant. It had been evident previously that males strived more for success in sport (Findlay and Bowker, 2009; Gill, 1988) and that they participated in sports substantially more often than girls and women in general (Deaner et al., 2012). However, it appeared that in the KR group, the motivation arising from the feedback (velocity displayed) stimulated women in the same way as men.

The experiment was carried out within the regular faculty programme and schedule and, as a consequence, the participants were not available for a retention test to evaluate the long-term effects of the intervention. Different times of the delay of KR were not investigated; moreover, we did not monitor or evaluate precisely the KP feedback. Physical education students constituted rather a diverse population, therefore comparisons to elite athletes should be made with some caution. Additionally, in our study a smaller

ball weighing 100 grams less than the official size 3 ball used in handball by men and male youth over the age of 16 was utilised. Shooting with a lighter ball must have influenced shooting biomechanics resulting in different muscular activation and coordination of the muscles involved. The same balls were used to test the male and female participants; therefore, some precautions should be made regarding our findings since they could be compromised by different anthropometric characteristics of the hand and arm, which might also have influenced throwing performance. On the other hand, the size of the balls used should not have influenced our findings regarding the main aim of the study which was to investigate the effects of providing or not providing feedback on the ball velocity gain.

Limitations of the study listed above also present some issues to be considered in future studies. The results clearly showed that providing immediate 100% frequent KR for six weeks resulted in a three to four times greater increase of the velocity of the ball at release compared to the same intervention when KR was not provided. These differences were generally independent of gender. This information should encourage athletes and coaches to use KR frequently in sports where the velocity of a throwing projectile is of paramount importance. Nowadays, devices for measuring velocities of projectiles are readily available and easy to use. A shooting session (or one of the circuit conditioning stations) could be used without the necessity of presence of a goalkeeper; such an approach would be a valuable variation from typical sessions possibly augmenting velocity gain, engagement and motivation of the players.

## References

- Alexander R. Optimum timing of muscle activation for simple models of throwing. *J Theor Biol*, 1991; 150: 349-372
- Bennett D, Simmons R. Effects of precision of knowledge of results on acquisition and retention of a simple motor skill. *Percept Mot Skills*, 1984; 58: 785-786
- Bosco C, Komi P, Ito A. Prestretch potentiation of human skeletal muscle during ballistic movement. *Acta Physiol Scand*, 1981; 111: 135-140
- Calabrese G. Pitching mechanics, revisited. *Int J Sports Phys Ther*, 2013; 8(5): 652-60

- Chowdhary A, Challist J. Timing accuracy in human throwing. *J Theor Biol*, 1999; 201: 219-229
- Deaner R, Geary D, Puts D, Ham S, Kruger J, Fles E, Winegard B, Grandis T. A sex difference in the predisposition for physical competition: males play sports much more than females even in the contemporary U.S. *PLoS ONE*, 2012; 7
- Derenne C, Ho K, Murphy J. Effects of general, special and specific resistance training on throwing velocity in baseball: a brief review. *J Strength Cond Res*, 2001; 15(1): 148-56
- Escamilla R, Andrews J. Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. *Sports Med*, 2009; 39: 569-90
- Findlay L, Bowker A. The link between competitive sport participation and self-concept in early adolescence: a consideration of gender and sport orientation. *J Youth Adolesc*, 2009; 38: 29-40
- Gill D. Gender differences in competitive orientation and sport participation. *Int J Sports Psychol*, 1988; 19: 145-159
- Greziou A, Gissis I, Sotiropoulos A, Nikolaidis D, Souglis A. Muscle-contraction properties in overarm throwing movements. *J Strength Cond Res*, 2006; 20: 117-23
- Hancock R, Hawkins R. Applications of electromyography in the throwing shoulder. *Clin Orthop Relat Res*, 1996; 330: 84-97
- Hermassi S, Chelly M, Fathloun M, Shephard R. The effect of heavy- vs. moderate-load training on the development of strength, power, and throwing ball velocity in male handball players. *J Strength Cond Res*, 2010; 24(9): 2408-18
- Hirashima M, Kadota H, Sakurai S, Kudo K, Ohtsuki T. Sequential muscle activity and its functional role in the upper extremity and trunk during overarm throwing. *J Sports Sci*, 2002; 20: 301-10
- Keller M, Lauber B, Gehring D, Leukel C, Taube W. Jump performance and augmented feedback: immediate benefits and long-term training effects. *Hum Mov Sci*, 2014; 36: 177-89
- Kelly B, Backus S, Warren R, Williams R. Electromyographic analysis and phase definition of the overhead football throw. *Am J Sports Med*, 2002; 30: 837-44
- Kernodle M, Carlton L. Information feedback and the learning multiple-degree-of-freedom activities. *J Mot Behav*, 1992; 24: 187-96
- Magill R, Wood C. Knowledge of results precision as a learning variable in motor skill acquisition. *Res Q Exerc Sport*, 1986; 57: 170-173
- Magill R. *Motor Learning and Control: Concepts and Applications*. New York: McGraw-Hill; 2011
- Moran K, Murphy C, Marshall B. The need and benefit of augmented feedback on service speed in tennis. *Med Sci Sports Exerc*, 2012; 44: 754-60
- Putnam C. Sequential motion of body segments in striking and throwing skills: Descriptions and Explanations. *J Biomech*, 1993; 26(1): 125-135
- Reeve T, Dornier L, Weeks D. Precision of knowledge of results: Consideration of the accuracy requirements imposed by the task. *Res Q Exerc Sport*, 1990; 61: 284-290
- Salmoni A, Ross D, Dill S, Zoeller M. Knowledge of results and perceptual motor learning. *Hum Mov Sci*, 1983; 2: 77-89
- Schmidt R, Wrisberg C. *Motor Learning and Performance: A Situation-based Learning Approach*. Champaign, IL: Human Kinetics; 2008
- Swinnen S, Schmidt R, Nicholson D, Shapiro D. Information feedback for skill acquisition: Instantaneous knowledge of results degrades learning. *J Exp Psychol Learn Mem Cogn*, 1990; 16(4): 706-716
- van den Tillaar R, Ettema G. Instructions emphasizing velocity, accuracy, or both in performance and kinematics of overarm throwing by experienced team handball players. *Percept Mot Skills*, 2003; 97: 731-42



- van den Tillaar R. Effect of different training programs on the velocity of overarm throwing: a brief review. *J Strength Cond Res*, 2004; 18(2): 388-96
- van den Tillaar R, Ettema G. A comparison of kinematics between overarm throwing with 20% underweight, regular, and 20% overweight balls. *J Appl Biomech*, 2011; 27(3): 252-7
- Wagner H, Pfusterschmied J, Von Duvillard S, Müller E. Skill-dependent proximal-to-distal sequence in team-handball throwing. *J Sports Sci*, 2012; 30: 21-9
- Weber A, Kontaxis A, O'Brien S, Bedi A. The biomechanics of throwing: simplified and cogent. *Sports Med Arthrosc*, 2014; 22: 72-9
- Winstein C, Schmidt R. Reduced frequency of knowledge of results enhances motor skill learning. *J Exp Psychol Learn Mem Cogn*, 1990; 16: 677-691
- Wulf G, Shea C, Matschiner S. Frequent feedback enhances complex motor skill learning. *J Mot Behav*, 1998; 30: 180-9

**Corresponding author:****Igor Štirn**

University of Ljubljana, Faculty of Sport, Faculty of Sport,  
Gortanova 22, 1000, Ljubljana, Slovenia  
Phone no.: +386 1520 7799  
Fax.no.: +386 1520 7750  
E-mail: igor.stirn@fsp.uni-lj.si