©Journal of Sports Science and Medicine (2015) **14,** 41-46
http://www.jssm.org

Research article

Self-Paced and Temporally Constrained Throwing Performance by Team-Handball Experts and Novices without Foreknowledge of Target Position

Elissavet N. Rousanoglou [1]✉, Konstantinos S. Noutsos [2], Ioannis A. Bayios [2] and Konstantinos D. Boudolos [1]
[1] Sport Biomechanics Lab, Department of Sport Medicine & Biology of Exercise, and [2] Department of Sport Games, School of Physical Education & Sport Science, National & Kapodistrian University of Athens, Greece

Abstract
The fixed duration of a team-handball game and its continuously changing situations incorporate an inherent temporal pressure. Also, the target's position is not foreknown but online determined by the player's interceptive processing of visual information. These ecological limitations do not favour throwing performance, particularly in novice players, and are not reflected in previous experimental settings of self-paced throws with foreknowledge of target position. The study investigated the self-paced and temporally constrained throwing performance without foreknowledge of target position, in team-handball experts and novices in three shot types (Standing Shot, 3Step Shot, Jump Shot). The target position was randomly illuminated on a tabloid surface before (self-paced condition) and after (temporally constrained condition) shot initiation. Response time, throwing velocity and throwing accuracy were measured. A mixed 2 (experience) X 2 (temporal constraint condition) ANOVA was applied. The novices performed with significantly lower throwing velocity and worse throwing accuracy in all shot types ($p = 0.000$) and, longer response time only in the 3Step Shot ($p = 0.013$). The temporal constraint (significantly shorter response times in all shot types at $p = 0.000$) had a shot specific effect with lower throwing velocity only in the 3Step Shot ($p = 0.001$) and an unexpected greater throwing accuracy only in the Standing Shot ($p = 0.002$). The significant interaction between experience and temporal constraint condition in throwing accuracy ($p = 0.003$) revealed a significant temporal constraint effect in the novices ($p = 0.002$) but not in the experts ($p = 0.798$). The main findings of the study are the shot specificity of the temporal constraint effect, as well as that, depending on the shot, the novices' throwing accuracy may benefit rather than worsen under temporal pressure.

Key words: Throwing velocity, throwing accuracy, visual control, postural control, expertise level.

Introduction

Throwing performance has been established as a determinant factor in winning a team-handball game (Bayios et al., 2001; Gorostiaga et al., 2005; Laffaye et al., 2012; van den Tillaar and Ettema, 2003; 2006; Wagner et al., 2011; 2012). The above-mentioned studies evaluated the components of throwing performance after ball release (ball-throwing velocity and accuracy) in self-paced team-handball shots. However, the self-paced execution of the throwing movement is rarely encountered in the course of a real team-handball game. With the exception of the penalty shot, the continuously changing nature of the event and the fixed game duration incorporate an inherent temporal pressure on throwing performance.

The temporally constrained execution may worsen throwing performance due to the perception that the time allowed is not adequate for elaborate movement programming (Goonetilleke et al., 2009; Williams et al., 2002). In throwing tasks, such as pistol (Goonetilleke et al., 2009) and billiard shooting (Williams et al., 2002), aiming accuracy was significantly decreased when the available time was constrained at 75% and 50% of the self-paced execution. This reduction of far-aiming accuracy under temporal pressure is attributed to the decreased efficiency in picking up the target's visual information (Goonetilleke et al., 2009; Vickers et al., 2000; Williams et al., 2002) due to a shorter "quiet eye" (the gaze fixation on the target for a minimum of 100 ms within a 3º visual angle, as defined by Vickers in 1996). Having less time available to initiate and execute an aiming task seems to have different effects on experts and novices. In temporally constrained situations that limit, rather than encourage, attention to execution, the experts' performance excels, whereas the performance of novices worsens (Beilock et al., 2004). In throwing or shooting tasks, the novices' reduction in aiming accuracy is attributed to their inefficient visual (Jafarzadehpur et al., 2007; Vickers et al., 2000; Williams et al., 2002) as well as postural control (Goonetilleke et al., 2009; Paillard and Noé, 2006; Paillard et al., 2011) and, their greater dependence on vision to control posture (Paillard and Noé, 2006; Paillard et al., 2011).

Overall, the vast majority of research about the negative influence of temporal constraints in far-aiming accuracy regards rather static tasks, such as dart throwing (Vickers et al., 2000), billiard shooting (Williams et al., 2002) and rifle shooting (Goonetilleke et al., 2009). In dynamic far-aiming tasks, such as those encountered in ball sports, the respective information appears limited to soccer kicks (Jordet et al., 2009). To the best of our knowledge, no previous research has been performed on temporally constrained performance in overhead throwing sports. In basketball shots, constraining the timing of picking up the target's visual information has a negative influence on aiming accuracy (de Oliveira et al., 2006). However, aside from the prerequisite to initiate the throw on the verbal command "Go", the time available to execute the basketball shot was unconstrained in both the experimental settings of de Oliveira et al. (2006) and Oudejans et al. (2002).

Received: 26 May 2014 / Accepted: 10 October 2014 / Published (online): 01 March 2015

Team-handball differs from previously examined static (i.e. dart throwing) or dynamic (i.e. basketball) far-aiming tasks in that the shooting target is not located at a specific pre-determined site and its dimensions are not geometrically defined. In team-handball, as in soccer, the target location is ultimately determined by the player's online interceptive processing of visual information as the area that the goalkeeper is not able to defend. These target characteristics set disadvantageous requisites for novice performers who are likely to experience insufficient motor organisation and execution due to their low visual (Jafarzadehpur et al., 2007; Vickers, 1996; Vickers et al., 2000; Williams et al., 2002) and postural control (Goonetilleke et al., 2009; Paillard and Noé, 2006; Paillard et al., 2011). Furthermore, the target-related ecological limitations commented on in previous team-handball studies (Wagner et al., 2012) indicate that, real-game target characteristics are not adequately reflected in their experimental settings. In such studies, participants were asked to throw at already-known, pre-determined target locations which were available for viewing throughout the various experimental conditions (Bourne et al., 2011; Garcia et al., 2013; Gutiérrez-Dávila et al., 2013; van den Tillaar and Ettema, 2003, 2006; Wagner et al., 2012). However, even without external objects to process, the foreknowledge of target positions allows participants the endogenous preparation for the task (Ruge et al., 2013). The foreknowledge of target position and the self-paced execution of the throwing movement in previous studies contradict the online interceptive decision of the target's position during an actual team-handball game. Reasoned on the above-mentioned research results, we hypothesized that throwing without foreknowledge of target position imposes a temporal constraint that would have a significant negative effect on the novice's throwing performance, whereas, it would not significantly affect the experts' performance. Thus, this study aimed to investigate self-paced and temporally constrained throwing performance by team-handball experts and novices without foreknowledge of the target's position.

Methods

Participants

The study examined the performance of 30 participants who were separated into an expert group and a novice group. The expert group comprised 15 males (age, 24.9 ± 2.9 yrs; height, 1.81 ± 0.06 m; body mass, 83.1 ± 5.3 kg) who were among the best scorers in the first division of the Team-Handball National League (training experience of 12.3 ± 3.0 yrs). The novice group comprised of 15 male students of Physical Education and Sport Science (age, 21.7 ± 0.9 yrs; height 1.82 ± 0.06 m; body mass, 77.1 ± 6.4 kg) who had completed a 4 month team-handball course (3 hours/week). All participants were free of medical problems or pain that could affect their performance for at least six months prior to the study, and they all signed an informed consent form that described the testing procedure in detail. The work reported was approved by the institutional review board and conformed to the principles outlined in the Declaration of Helsinki.

Procedures

Each participant was allowed a 15-minute warm-up, including general and shoulder specific mobility exercises, stretching exercises and familiarization with the protocol. Each participant was free to choose his own usual warm-up exercises. All participants were instructed to complete team-handball shots from the 7 m penalty line using a standard official ball (0.44 kg, 58.1 cm) under self-paced (no temporal constraint condition) and temporally constrained shots (temporal constraint condition). In each temporal constraint condition, they performed five trials of the three most common types of team-handball shots: the Standing Shot, the 3Step Shot and the Jump Shot (Wagner et al., 2008). In the Standing Shot, the participants waited for the initiation of the trial at the 7 m penalty line. In the 3Step Shot and the Jump Shot, the participants waited for the initiation of their run-up at a 3 m distance behind the penalty line (run-up approach distance) (Figure 1). The temporal constraint conditions were counterbalanced within the group of the experts and the group of the novices. In each temporal constraint condition, a Latin square randomization design was applied for the three shot types. A one-minute rest was provided between the trials in each temporal constraint condition, and a five-minute rest was provided between temporal constraint conditions.

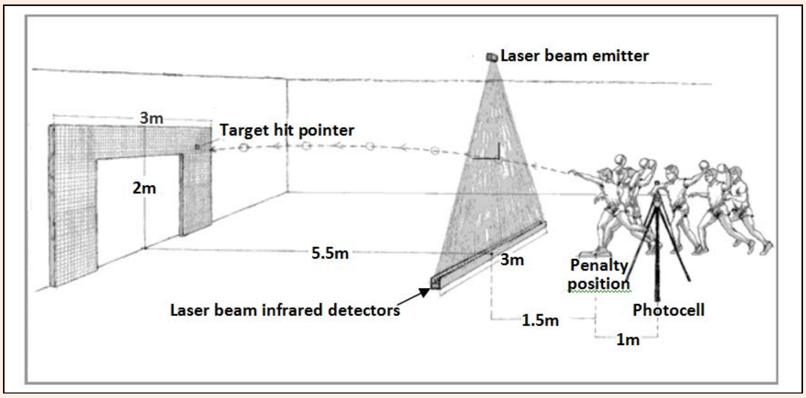

Figure 1. Schematic representation of the tabloid surface of target hit pointers, an illuminated target hit pointer, the laser system, the laser beam infrared detectors, the photocell and a participant during a 3Step Shot data collection.

Knowledge of target position and throwing accuracy

Visual information regarding the target position was provided with an innovative electronic device described in detail by Bayios et al. (1998) (see Figure 1). Briefly, the device featured a Π-shaped tabloid surface, which functioned as a "target hit pointer", and a "hit detector" surface of 3.48 m^2 (top horizontal tabloid: 180 × 60 × 2 cm, left and right vertical tabloids: 200 x 60 x 2 cm) (Figure 1). The tabloid surface was firmly attached to the inner side of a team-handball goal post (300 × 200 × 8 cm) and included a total of 2.130 light emitting diodes (LEDs). The LEDs formed a net (40 × 40 mm squares) of 1946 "target hit pointers" (672 locations in the horizontal tabloid and 602 locations in the left and right vertical tabloids, respectively). The LED net was interwoven with a net of metal strips (40 × 40 mm squares) that served as "hit detectors" (10 mm wide, 1 mm thick, inter-distance of 2 mm). The "target hit pointers" were randomly illuminated with an electronic programmer. When the ball hit the tabloid surface, the "hit detectors" transferred the coordinates of the hit point to the central unit with 1 mm accuracy. The shot accuracy was determined by the throwing error which was calculated as the difference between the coordinates of the illuminated "target hit pointer" and the detected hit point and was expressed in centimetres (cm).

Self-paced and temporally constrained conditions

In the self-paced condition, the participant was allowed his preferred amount of time to initiate the shot after the "target hit pointer" was illuminated on the tabloid surface. In the temporally constrained Standing Shot, the examiner activated the central unit that would trigger the illumination of the "target hit pointer" together with the verbal command "Go". In the 3Step Shot and the Jump Shot temporally constrained conditions, the "target hit pointer" was illuminated after the initiation of the trial when, during the run-up approach, the participant interrupted a photocell beam emitting 1 m after the penalty line (Figure 1). In both the self-paced and temporally constrained conditions, the "target hit pointer" was turned off as soon as the ball hit the tabloid surface. The difference between the time point that the "target hit pointer" was illuminated on the tabloid surface and the time point that the ball hit the tabloid surface was defined as the response time and was expressed in seconds (s).

Ball-throwing velocity

The ball-throwing velocity was measured by an innovative electronic device (Bayios et al., 2001). Briefly, the device comprised a laser beam emitter (positioned at ceiling level at 1.5 m after the penalty line) and an electronic system of laser beam infrared detectors which was connected to a digital pulse counter (positioned on the floor level with an inter-detector distance of 4 cm) (Figure 1). The laser beam was emitting vertically to the floor, interfacing the infrared detectors at a length of 3 m (Figure 1). The duration that the laser beam was interrupted by the ball (beam interruption time) was recorded by the digital pulse counter in microseconds. Then the ball velocity was calculated by dividing the ball's diameter (178 mm) by the beam interruption time and was expressed in $m{\cdot}s^{-1}$.

Statistical analysis

A mixed 2 X 2 ANOVA was applied separately in each type of shot to test the interaction between the independent factor of experience (novices versus experts) and the repeated factor of temporal constraint conditions (self-paced versus constrained performance) as well as the main effects of the two factors. The variables inserted in the statistical analysis were those of ball-throwing velocity, throwing accuracy and response time; the individual average across the five trials was calculated for each participant and inserted as the value of each variable. If a significant interaction was detected the contingent protocol was follow up t-tests. Statistical significance was set at $p \leq 0.05$ for all analyses (SPSS 21.0).

Results

Experience effect

The novices performed with significantly lower throwing velocity (p = 0.000 for all shot types) and worse throwing accuracy (p = 0.000 for all shot types) (Figure 2). The novices performed with longer response times, however the differences yielded statistical significance only in the 3Step Shot (p = 0.013) (Standing Shot: p = 0.707, Jump Shot: p = 0.146) (Figure 2).

Temporal constraint effect

The overall results show that, in the temporally constrained performance throwing velocity was lower, throwing accuracy was reduced (with a single exception described below) and response time was shorter. For throwing velocity the single significant difference was found in the 3Step Shot (p = 0.001) (Standing Shot: p = 0.067, Jump Shot: p = 0.200), with no significant interaction between experience and temporal constraint (Standing Shot: p = 0.322, 3Step Shot: p = 0.505, Jump Shot: p = 0.233). In throwing accuracy, there was a significant temporal constraint effect but only in the Standing Shot (p = 0.002) (3Step Shot: p = 0.272, Jump Shot: p = 0.246) with a significant interaction between experience and temporal constraint (p = 0.003) (3Step Shot: p = 0.590 and Jump Shot: p = 0.808). The follow up t-tests revealed a significant change of throwing accuracy in the temporally constrained Standing Shot in the novices (p = 0.002) but not in the experts (p = 0.798). For response time, differences were significant in all types of shot at p = 0.000, with no significant interaction between experience and temporal constraint (Standing Shot: p = 0.211, 3Step Shot: p = 0.172, Jump Shot: p = 0.063).

Discussion

The purpose of the study was to compare the self-paced and temporally constrained throwing performance in team-handball experts and novices without foreknowledge of target position. Our hypothesis was that throwing without foreknowledge of target position imposes a temporal constraint that would have a significant negative effect on the novices' throwing performance, whereas, it would not significantly affect the experts' performance. The main finding of our study is that there was a shot specific confirmation or rejection of our hypothesis, with an unexpected direction of the temporal constraint effect in the novices' throwing accuracy. In specific, throwing velocity was significantly affected only in the 3Step Shot, not only in the novices but also in the experts, while, throwing accuracy was affected only in the Standing Shot, with a positive rather than negative effect in the novices.

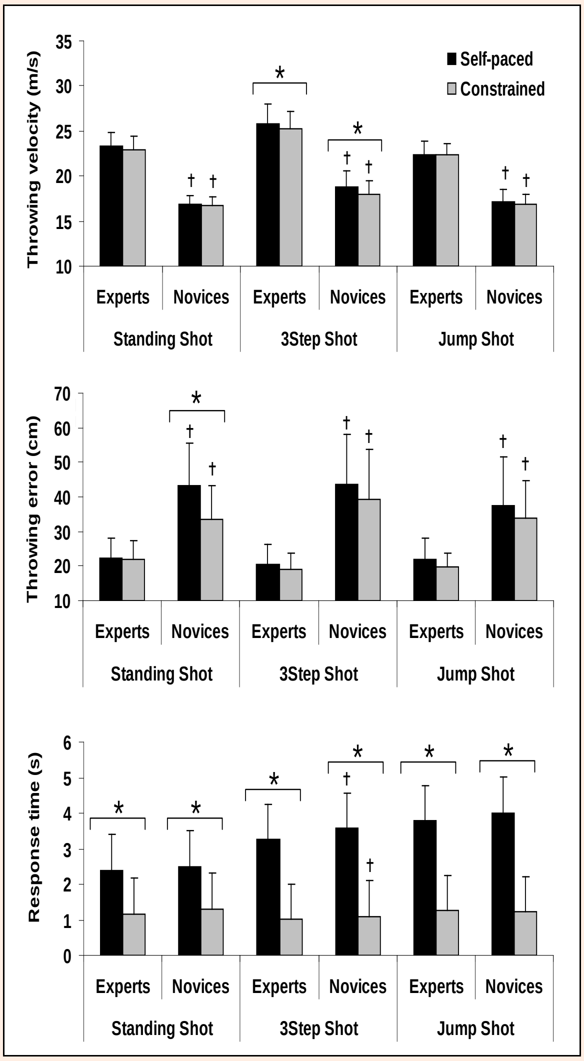

Figure 2. Mean and standard deviation of the individual averages for throwing velocity (Top), throwing error (Center) and response time (Bottom), in the self-paced (black bars) and the temporally constrained (grey bars) throws performed by the experts and the novices, in the Standing Shot, the 3Step Shot and the Jump Shot. †: significant differences between the experts and the novices ($p \le 0.05$), * significant differences between the self-paced and the temporally constrained condition ($p \le 0.05$).

The training experience of the experts was comparable to that described for international level players, whereas our novices could be considered at a lower level (Gorostiaga et al., 2005; Laffaye et al., 2012; van den Tillaar & Ettema, 2006; Wagner et al., 2012). As expected, we found significantly greater ball-throwing velocity and better throwing accuracy in the experts than the novices with ball-throwing velocities within the range previously reported (Garcia et al., 2013; Gorostiaga et al., 2005; Gutiérrez-Dávila et al., 2013; Laffaye et al., 2012; van den Tillaar and Ettema, 2003, 2006; Wagner et al., 2011; Wagner et al., 2012). Also in agreement with previous studies, the ball-throwing velocity was greater in the 3Step Shot, followed by the Jump Shot and the Standing Shot; throwing accuracy did not differ among the three types of shots (Bayios et al., 2001; Wagner et al., 2011; 2012).

We found a shot specificity in the change of throwing velocity and throwing accuracy which, most likely, indicates that the influence of temporal constraint may be determined by task specific biomechanical constraints. The presence or absence of ground contact together with the discrete differences of the lower body movements in the three types of shots are associated with different postural control demands. In particular, the Standing Shot involves keeping the lead foot on the floor, thus static postural control is more important throughout the throwing kinetic chain. In the 3Step Shot, one foot is planted on the floor after a 3 step run-up. Therefore, an effective transition from dynamic to static postural control is important for the efficient termination of the forward momentum and the provision of a stable support base to execute the throwing kinetic chain. Finally, the Jump Shot involves executing a single-leg vertical jump after the run-up with the throwing movement initiated and completed while the body is in the air. Such a situation demands dynamic postural control in the absence of ground contact. In throws such as the team-handball Standing Shot, research corroborates the existence of whole body postural control differences with respect to the temporal pressure (Ilmane and LaRue, 2008). Such a disturbance in head posture control and stabilization may be particularly important for aiming accuracy, because the control of head postural provides a fixed reference for the correct shoulder and body orientation for ball propulsion and release (Ripoll et al., 1986). The interaction between experience and temporal constraint condition also indicated a shot specificity of the temporal constraint's influence, with similar effect in both the experts and the novices in the 3Step Shot but dissimilar effect in novices than experts in the Standing Shot. This dissimilarity may be associated to the less efficient postural and visual control of the novices. Previous studies report that visual (Jafarzadehpur et al. 2007; Vickers, 1996; Vickers et al., 2000; Williams et al., 2002) and postural control efficiency (Goonetilleke et al., 2009; Paillard and Noé, 2006; Paillard et al., 2011) distinguishes the expertise level and allows expert players less dependence on vision to control posture (Paillard and Noé, 2006; Paillard et al., 2011). Thus the task specific postural control demands in combination with the level of expertise may explain the shot specificity of the temporal constraint effect.

The unexpected increase of throwing accuracy in the novices' Standing Shot is not easy to explain. One possible explanation could be that depending on the task demands, novices may also benefit from limited execution time, as previously reported for experts (Beilock et al. 2004), however, this inference can not be adequately supported by our research design. This finding was unexpected because far-aiming accuracy is reported to worsen when the available execution time is reduced at 75% and 50% of the self-paced time in static tasks such as the billiard (Williams et al., 2002) and pistol shooting (Goonetilleke et al., 2009). In our study, the reduction of available execution time is reflected in the significant decrease of temporally constrained response times at about 50% to 70% of the self-paced condition. The decrease of far-aiming accuracy when under temporal pressure, is attributed to the reduction of the visual efficiency in information pick-up, typically recorded as a shorter "quiet eye" duration in billiard (Williams et al., 2002) and pistol shooting (Goonetilleke et al., 2009). Similar results are reported for dynamic far-aiming tasks encountered in soccer (Jordet et al., 2009) and basketball (de Oliveira et al., 2006; Oudejans et al., 2002). The "quiet eye" duration was not measured in our study and, to the best of our knowledge, there is no relevant research information in team-handball shots. Thus, the inclusion of visual control measures in future team-handball studies could elucidate such unexpected results of throwing performance.

The testing conducted did not reflect the numerous situations faced by players during actual team-handball competition, which is a limitation also found in similar team-handball studies (Wagner et al., 2012). However, compared to previous studies, we believe our target electronic device (Bayios et al., 1998) increased the ecological setting of the experiment by enabling target characteristics that more closely replicate actual game shooting conditions. In previous handball studies, players were asked to throw at known, pre-determined locations that were continuously visible by players throughout various experimental conditions (Bourne et al., 2011; Garcia et al., 2013; Gutiérrez-Dávila et al., 2013; Wagner et al., 2012; van den Tillaar and Ettema, 2003; 2006). Such an experimental setting allows foreknowledge of the target position; this situation facilitates the endogenous preparation for the task even without external objects to process (Ruge et al., 2013; Sohn and Carlson, 2000). The increased ecological setting in our study is further enhanced due to the potential for 1946 "target hit pointers" anywhere within the 3.84 m^2 Π-shaped tabloid surface (Bayios et al., 1998). This number of target positions far exceeds the number of targets previously used, including one (van den Tillaar and Ettema, 2003, 2006; Wagner et al., 2012), four (Bourne et al., 2011; Gutiérrez-Dávila et al., 2013) and ten target positions (Garcia et al., 2013).

The absence of a goalkeeper is a limitation of the study since its presence affects throwing velocity (Rivilla-Garcia et al., 2011a) and throwing accuracy (Rivilla-Garcia et al., 2011b) in a negative way with the effect being greater at lower expertise levels. However, this was also a limitation of many other studies on handball throwing (Garcia et al., 2013; Gutiérrez-Dávila et al., 2013; van den Tillaar and Ettema, 2003; 2006; Wagner et al., 2012). Furthermore, this limitation is not reflected in our results since the ball-throwing velocity was within the previously reported range for experts and novices (Garcia et al., 2013; Gorostiaga et al., 2005; Gutiérrez-Dávila et al., 2013; Laffaye et al., 2012; van den Tillaar and Ettema, 2003; 2006; Wagner et al., 2011; 2012).

Conclusion

In conclusion, as expected the novices performed with lower throwing velocity and worse throwing accuracy. The main finding of the study is that the temporal constraint effect was shot specific; throwing velocity was significantly reduced in both the novices and the experts but only in the 3Step Shot, while throwing accuracy was significantly affected in the novices but only in the Standing Shot. Furthermore, the novices' throwing accuracy was increased rather than decreased in the Standing Shot which could indicate that, depending on the shot demands, the novices may also benefit from limited execution time, as previously reported for experts.

References

Bayios, I., Anastasopoulou, E., Sioudris, D. and Boudolos. K. (2001) Relationship between isokinetic strength of the internal and external shoulder rotators and ball velocity in team handball. *The Journal of Sports Medicine and Physical Fitness* **41,** 229-235.

Bayios, I., Georgiadis, G. and Boudolos, K. (1998) An innovative device for measuring accuracy of throwing in handball. In: *Proceedings of the 16th Conference of the International Society of Biomechanics in Sports* (ISBS). Available from URL: https://ojs.ub.uni-konstanz.de/cpa/article/view/1593/0

Beilock, S.L., Carr, T.H., MacMahon, C. and Starkes, J.L. (2002) When paying attention becomes counterproductive: impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *Journal of Experimental Psychology* **8,** 6-16.

Bourne, M., Bennett, S.J., Hayes, S.J. and Williams, A.M. (2011) The dynamical structure of handball penalty shots as a function of target location. *Human Movement* Science **30,** 40-55.

de Oliveira, R.F., Oudejans, R.R. and Beek, P.J. (2006) Late information pick-up is preferred in basketball jump shooting. *Journal of Sports Sciences* **24,** 933-940.

García, J.A., Sabido, R., Barbado, D. and Moreno, J.F. (2013) Analysis of the relation between throwing speed and throwing accuracy in team-handball according to instruction. *European Journal of Sport Science* **13,** 149-154.

Goonetilleke, R.S., Hoffmann, E.R. and Lau, W.C. (2009) Pistol shooting accuracy as dependent on experience, eyes being opened and available viewing time. *Applied Ergonomics* **40,** 500-508.

Gorostiaga, E.M., Granados, C., Ibanez, J. and Izquierdo, M. (2005) Differences in physical fitness and throwing velocity among elite and amateur male handball players. *International Journal of Sports Medicine* **26,** 225-232.

Gutiérrez-Dávila, M., Ortega-Becerra, M., Párraga, J., Campos, J. and Rojas-Ruiz, F.J. (2013) Influence of the throwing direction on biomechanics of movement patterns in handball throws. *Revista de Ciencias del Deporte* **9,** 59-70.

Ilmane, N. and LaRue, J. (2008) Modulation of anticipatory postural adjustments in a complex task under different temporal constraints. *Motor Control* **12,** 330-347.

Jafarzadehpur, E., Aazami, N. and Bolouri, B. (2007) Comparison of saccadic eye movements and facility of ocular accommodation in female volleyball players and non-players. *Scandinavian Journal of Medicine and Science in Sports* **17,** 186-190.

Jordet, G., Hartman, E. and Sigmundstad, E. (2009) Temporal links to performing under pressure in international soccer penalty shootouts. *Psychology of Sport and Exercise* **10,** 621-627.

Laffaye, G., Debanne, T. and Choukou, M.A. (2012) Is the ball velocity dependent on expertise? A multi-dimensional study in handball. *International Journal of Performance Analysis in Sport* **12,** 629-642.

Oudejans, R.R., van de Langenberg, R.W. and Hutter, R.I. (2002) Aiming at a far target under different viewing conditions: visual control in basketball jump shooting. *Human Movement* Science **21,** 457-480.

Paillard, T., Margnes, E., Portet, M. and Breucq, A. (2011) Postural ability reflects the athletic skill level of surfers. *European Journal of Applied Physiology* **111,** 1619-1623.

Paillard, T., and Noé, F. (2006) Effect of expertise and visual contribution on postural control in soccer. *Scandinavian Journal of Medicine* and *Science in Sports* **16,** 345-348.

Ripoll, H., Bard, C. and Paillard, J. (1986) Stabilization of head and eyes on target as a factor in successful basketball shooting. *Human Movement Science* **5,** 47-58.

Rivilla-Garcia, J., Grande, I., Sampedro, J. and Van Den Tillaar, R. (2011a) Influence of opposition on ball velocity in the handball jump throw. *Journal of Sports Science and Medicine* **1**0, 534-539.

Rivilla-Garcia, J., Navarro, F. and Sampedro, J. (2011b) Influence of the opposition in throwing accuracy in elite and amateur handball players. *Revista de Ciencias del Deporte* **7,** 17-25.

Ruge, H., Jamadar, S., Zimmermann, U. and Karayanidis, F. (2013) The many faces of preparatory control in task switching: reviewing a decade of fMRI research. *Human Brain Mapping* **34,** 12-35.

Sohn, M.H. and Carlson, R.A. (2000) Effects of repetition and foreknowledge in task-set reconfiguration. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **26,** 1445-1460.

van den Tillaar, R. and Ettema, G. (2003) Influence of instruction on velocity and accuracy of overarm throwing. *Perceptual and Motor Skills* **96,** 423-434.

van den Tillaar, R. and Ettema, G. (2006) A comparison between novices and experts of the velocity-accuracy trade-off in overarm throwing. *Percept Mot Skills* **103,** 503-514.

Vickers, J.N., Rodrigues, S.T. and Edworthy, G. (2000) Quiet eye and accuracy in the dart throw. *International Journal of Sports Vision* **6,** 30-36.

Vickers, J.N. (1996) Visual control while aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance* **22,** 342-354.

Wagner, H., Kainrath, S. and Müller, E. (2008) The correlation of level of performance, throwing quality and selected technique-tactical parameters. *Leistungssport* **38,** 35-41. (In German).

Wagner, H., Pfusterschmied, J., Klous, M., von Duvillard, S.P. and Müller, E. (2011) Performance and kinematics of various throwing techniques in team-handball. *Journal of Sports Science and Medicine* **10,** 73-80.

Wagner, H., Pfusterschmied, J., Klous, M., von Duvillard, S.P. and Müller, E. (2012) Movement variability and skill level of various throwing techniques. *Human Movement Science* **31,** 78-90.

Williams, A.M., Singer, R.N. and Frehlich, S.G. (2002) Quiet eye duration, expertise, and task complexity in a near and far aiming task. *Journal of Motor Behavior* **34,** 197-207.

Key points

- The temporal constraint induced a shot specific significant difference in throwing velocity in both the experts and the novices.
- The temporal constraint induced a shot specific significant difference in throwing accuracy only in the novices.
- Depending on the shot demands, the throwing accuracy of the novices may benefit under temporally constrained situations.

AUTHORS BIOGRAPHY

Elissavet N. ROUSANOGLOU

Employment

Assistant Professor in Sport Biomechanics, School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Greece

Research interests

Muscle mechanics, EMG, motor control

Degree

MSc, PhD

E-mail: erousan@phed.uoa.gr

Konstantinos S. NOUTSOS

Employment

Lecturer in Handball Specialized Training, School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Greece

Degree

PhD

Research interests

Expertise differences in handball performance, Sport-specific anthropometric differences

E-mail: knutsos@phed.uoa.gr

Ioannis A. BAYIOS

Employment

Professor in Handball Specialized Training, School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Greece

Research interests

Expertise differences in handball performance, Sport-specific anthropometric differences

Degree

PhD

E-mail: ibayios@phed.uoa.gr

Konstantinos D. BOUDOLOS

Employment

Full Professor in Sport Biomechanics, School of Physical Education and Sport Sciences, National and Kapodistrian University of Athens, Greece

Degree

PhD

Research interests

Human performance, Kinesiology of athletic and daily movement, Enhancement of athletic technique, Sport-specific age differences, Ergonomics for daily living.

E-mail: cbountol@phed.uoa.gr

✉ **Elissavet N. Rousanoglou**

Ethnikis Antistasis 41, Daphne, 172-37, Athens, Greece