VARIABILITY IN OVERARM THROWING WITH RESISTANCE IN EXPERIENCED HANDBALL PLAYERS

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The purpose of this study was to investigate variability in overarm throwing kinematics with different wearable resistance conditions in handball players as increased variability was expected when testing throwing under new conditions (wearable resistance). Thirteen female handball players performed ten standing throws each under three conditions: normal throws, with light wearable resistance (LW) and heavy wearable resistance (HW), while 3D kinematic data of joint angles and angular velocities were measured with a camera-based motion capture system. The main findings in this study were that variability for all parameters, except a significant lower maximal angular velocity in the high weight condition, compared to the no weight condition, did not differ between the three conditions. It was concluded that wearable resistance had no effect upon variability.

KEYWORDS: mocap, kinematics, angular velocity

INTRODUCTION: Specific training can be understood as that the movements should be similar to the movement patterns used in competition. This has been in focus for a long time and is important in training for performance (Magill & Anderson, 2021). Specific training and variability are often seen as opposites. However, variability and specific training are both important for learning and development of skill (Shea & Morgan, 1979). Overarm throw with external weights attached on the forearm may be the most specific training method to train the throwing performance, besides throwing with heavier and lighter balls.
Variability in throwing within a player is often represented by the standard deviation (Fredriksen & van de Tillaar, 2022; van den Tillaar & Ettema, 2003; van den Tillaar & Ettema, 2007; van den Tillaar & Marques, 2011). Individuals have a certain trial-to-trial variability in their performance (Magill & Anderson, 2021). Marteniuk and Romanow (1983) found out that trial-to-trial variability was large in the first ten trials and the variability became lower after multiple trials. Consequently, when practicing in a new situation like e.g, throwing with wearable resistance attached to the forearm, it is expected that there would be much variability. Therefore, many study introduce familiarization sessions, before testing to avoid a learning effect (Skoufas et al., 2008; van den Tillaar & Ettema, 2011), but mostly these studies were performed with unexperienced subjects (Skoufas et al., 2008; van den Tillaar & Ettema, 2006). However, it is not known if there is more variability in throwing in new situations in experienced handball players. Therefore, the aim of this study was to investigate the variability between normal overarm throwing and throwing with different wearable resistance loads attached to the forearm without familiarization sessions before. Based upon earlier studies (Marteniuk & Romanow, 1983; van den Tillaar & Ettema, 2009) it was hypothesized that there would be more variability in kinematics when throwing with different wearable resistance conditions due to the inexperience of the players with conditions.

METHODS: To investigate variability in overarm throwing under new conditions, a within-subjects repeated measure design was used. The participants had to throw ten throws in each condition. There were three different conditions, no weight, low and high weight, and the order of the conditions was randomized to avoid effects of learning and fatigue. The weights were individualized and corrected by 50 g based on the participants body mass.

Table 1. Different weights attached to the forearm in the three conditions based on the participants body mass.

Body mass (kg)	No weight	Low weight (kg)	High Weight (kg)
<60	0	0.15	0.35
60-75	0	0.20	0.40
75-90	0	0.25	0.45
> 90	0	0.30	0.50

Thirteen experienced female handball players (age: 22.15 ± 2.8 years; body mass: 73.35 ± 11.2 kg; height: 171.62 ± 7.7 cm) participated in this study. After a 15 minutes individual warm-up consisted of throwing drills, reflective markers (2.6 cm in diameter) and a forearm sleeve were attached to the participants. The participants had to throw in a penalty throw situation, 7 m away from the target, always keeping the front foot on the ground ten times in each condition. Everything was mirrored for the left-handers. The participants were instructed to throw as hard as possible and try to hit the target.
An eight-camera 3D motion capture system (Qualisys, Gothenburg, Sweden) sampling at 240Hz was used to measure the position of the reflective markers. Motion capture data were exported to C3D files for segment modelling and analysis in Visual 3D software (C-motion, Germantown, MD, USA). All computations from the model-based data were smoothed with a low-pass Butterworth filter at a cut-off frequency at 15Hz. The joint angles and joint angular velocities were calculated in the distal to proximal orientation with a Cardan sequence in the order x-y-z. The maximal angle, and maximal angular velocity were calculated for the internal and external shoulder rotation, horizontal shoulder adduction, shoulder abduction, elbow extension and wrist flexion before ball release (Figure 1).

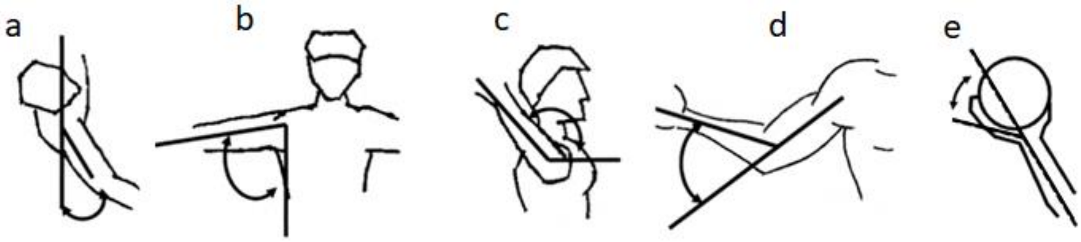

Figure 1. Definition of the kinematic parameters: (a) horizontal shoulder adduction, (b) shoulder abduction, (c) internal shoulder rotation, (d) elbow flexion and (e) wrist extension.

Descriptive statistics on variability were presented as the mean standard deviation over the ten throws per condition. This was calculated for each subject and the mean of this calculated over all subjects for each condition. Data were checked for normal distribution using the Shapiro-Wilk test. A one-way ANOVA with repeated measures within-subjects design was conducted to compare variability between the three conditions. When significant differences were observed, a post hoc test using the Bonferroni correction was applies. If sphericity was violating, results were reported with Greenhouse-Geisser corrections. A significance level of 0.05 was used to identify differences. Effect size (ES) was evaluated with η_p^2 (ETA partial squared), where <0.01–0.06 constitutes a small effect, <0.06–0.14 constitutes medium effect and >0.14 constitutes a large effect (Cohen, 1988). The statistical analyses were conducted in SPSS version 27.0 (IBM Corp., Armonk, NY, USA).

RESULTS: The mean variability in maximal angles over the ten throws varied from around 2 degrees (shoulder abduction) to 12 degrees (Shoulder horizontal adduction). No significant differences were found in the three conditions in maximal angles ($F \leq 4.02$, $p \geq 0.058$, $n_p^2 \leq 0.28$, Figure 2).
Furthermore, no significant differences in variability were found between the three conditions in maximal angular velocities ($F \leq 3.97$, $p \geq 0.063$, $\eta_p^2 \leq 0.49$), except for the variability in maximal angular velocity in elbow extension ($F = 5.56$, $p = 0.040$, $\eta_p^2 = 0.38$). Post hoc

comparison revealed that variability in maximal angular velocity in elbow extension was significantly lower when throwing with high weight compared to no weights (p = 0.006, Figure 3).

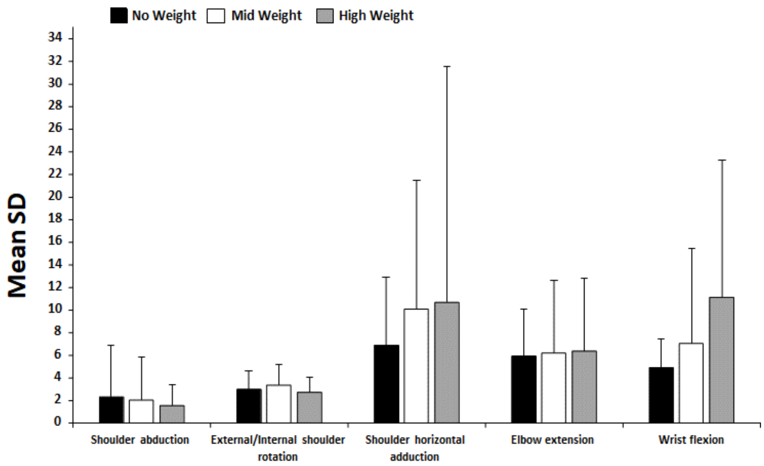

Figure 2. Variability (Mean ± SD) in maximal angles in all three conditions.

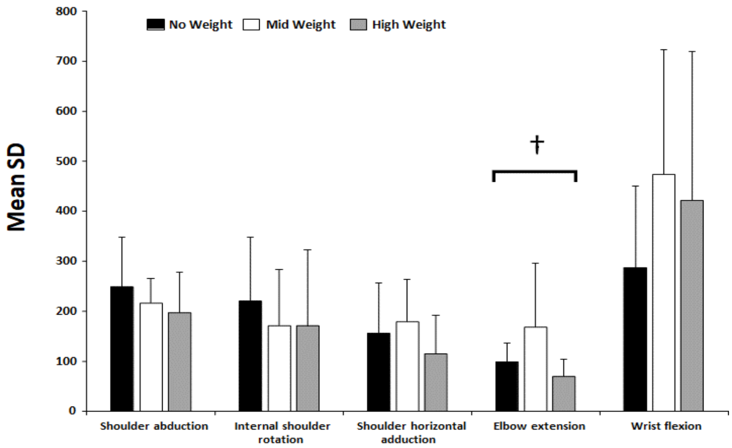

Figure 3. Variability (Mean ± SD) in maximal angular velocities in all three conditions.
† Indicates a significant difference between the marked conditions (p<0.05).

DISCUSSION: The aim of the study was to investigate the kinematic variability in overarm throwing in a known and new conditions (wearable resistance). The main findings were that the variability of all studied kinematic variables, except maximal angular velocity in elbow extension (which was lower in the high weight condition) were similar between the three conditions, while the opposite was expected. The scale of the variability within the players was comparable with an earlier study of van den Tillaar and Ettema (2009) who studied throws with dominant and non-dominant arm in experienced handball player. However, they found that there was more variability in internal shoulder rotation and shoulder horizontal adduction when throwing with the non-dominant arm. Throwing with non-dominant arm could be comparable with throwing in a new condition: different wearable resisted loaded throws as both were new for the players.

However, an explanation for the lack of variability can be given by the experience with the task. As nobody had thrown while wearing wearable resistance attached to the forearm, most players had experience with throwing heavier balls in training in their career. Thereby, the players already had their initial learning experience with extra weights during throwing even when the weight was not attached to their arm. The range of weights (LW and HW) attached to the forearm were comparable with throwing weighted balls of 0.6 and 0.8 kg. In an earlier study of van den Tillaar and Ettema (2004) on throwing with balls varying from 0.2 to 0.8 kg in experienced male handball players no differences in variability were visible between the throws with the different weights. They also did not perform a familiarization session before the test indicating that throwing with different weights perhaps are still the same motor skill and just variations of the same motor schema (Schmidt & Lee, 1999). Therefore, the experience of the players could be a reason why variability did not change when introducing new conditions. Shortcomings of this study were that we only investigated the variability in experienced players, and the range of loads attached could be too small to see a difference. Perhaps with more weight attached to the arm throwing technique would change due to possibility of compensation of different segments. Therefore, later studies should investigate novice handball players, and maybe with a larger range of loads attached to the forearm and the upper arm to consider if the variability increase with more loads attached.

CONCLUSION: Based on the findings of the present study, it was concluded that variability in throwing patterns did not change when new throwing conditions (loads attached to the forearm) were introduced without familiarization loads in experienced handball players, due to the experience of the players. Thereby, it is possible to conduct throwing studies with experienced handball players with different loads attached to the forearm without performing familiarization, since it seems that no learning effect occurs.

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