RELATIONSHIP BETWEEN CENTER OF MASS KINEMATICS AND BALL VELOCITY DURING JUMP THROWING IN HANDBALL

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The purpose of the present study was for investigating the relationships between body center of mass kinematic parameters and ball velocity during jump throwing in handball. Ten Handball players participated in this study, eight synchronized high-speed cameras were used at a 100 Hz frequency. SIMI 3D motion analyses system was used for capture and analyses, and SPSS statistical software was used to examine the relationships between COM kinematic parameters and ball velocity. The results indicated that the cocking phase and COM kinematical parameters are very important when evaluating jump throwing. In addition, the horizontal jump more associated with ball velocity than a vertical jump, although many situations in the game required the vertical jump.

KEY WORDS: Biomechanics, 3D kinematic analysis, Jump height.

INTRODUCTION: In handball competition, jump throw is the most used throw at the goal. Previous studies analyzed the performances of team handball players in a different aspects and concluded that angular kinematical parameters contributed significantly to differences in ball release velocity during throws and focused on upper limb angular kinematics when analysis jump throwing in handball (Serrien et al. 2015; van den Tillaar & Ettema, 2007; Wagner et al. 2010b; Wagner et al. 2010a; Wagner et al 2011; Wagner, Pfusterschmied, et al., 2014). And several studies emphasized the effects of aerobic fatigue, analysis the relation between throwing velocity and throwing accuracy, muscle power, and factors Influencing on ball throwing velocity in handball (García et al. 2013; Marques et al. 2007; Plummer & Oliver, 2016; Zapartidis et al. 2009).

Notwithstanding, several studies suggest that jump height for throws may be considered one of the important parameters in team handball. A high jump offers a good position to throw over the block of the rival defender, and associated by playing positions. Especially, when players shoot from the back court position or have more time for a shot and when attempting to react to goalkeeper actions (McKinon et al. 2004; Ravier & Demouge, 2016; Wagner et al. 2014). In our study we focused to examine the center of mass (COM) kinematics and its relationship with ball velocity, The COM is a point which the total body mass can be concentrated, and related to human balance and stability. COM variables are becoming a great interest in sports to determine the level of performance in many sports activity like running, football (Haran et al. 2004; Manolopoulos et al. 2006), volleyball (Wagner et al. 2009), judo (Imamura et al. 2006), long jump (Hay & Nohara, 1990). On the other hand, the center of mass (COM) excursions yield the best conditions for mastering balance and keeping the lower body more stable and effective. Additionally, the maximum change in COM velocity is considered an important parameter that is potentially related to performance (Mapelli et al., 2014). In context, all velocity consider a determinant of throwing performance in handball. Therefore, the purpose of the present study was for investigating the relationships between body center of mass kinematic parameters and ball velocity during jump throwing in handball.

METHODS: Ten Handball players participated in this study (age: 20.8 ± 1.21 years; body mass: 82.8 ± 8.57 kg; height: 189.6 ± 8.65 cm). After 15-minute warm-up, the participants

completed jump-throws from the 7-m penalty line after three running steps. A total of five successful attempts were recorded for each participant, one minute rest between attempts. The best attempt was selected for 3D linear kinematic analysis. The kinematic variables of center of body mass (displacement, velocity, and acceleration) on the three dimensions and resultant, and ball velocity were measured using a 3-D motion capture system (Simi Reality motion analysis V. 9.0.6; eight synchronized Basler (scA640-120gc) High-Speed Cameras were used at a 100 Hz frequency) that tracked the position of the reflective markers on anatomical landmarks according Hanavan model. The 3D coordinates were the X (medio-lateral), Y (anterior-posterior) and Z (vertical) directions respectively. The jump throwing skill was split to three phases (Cocking phase, Acceleration phase, and Following phase) include selected eight moments (Touch down, Maximum ground reaction force, Take-off, Maximum arm cocking, Maximum height of center of mass, Maximum height of throwing arm, Ball release, and Landing) during performance. To determine the relationships between COM kinematic parameters and ball velocity during throwing performance, these variables were correlated with the ball velocity using IBM SPSS statistics V. 22 software.

RESULTS AND DISCUSSION: This study was carried out to investigate the relationships between body center of mass kinematic parameters and ball velocity during jump throwing in handball. The results showed ball velocity was (21.82± 0.75 m/s) and the performance was examined according three phases (Cocking phase, Acceleration phase, and Following phase (Figure 1)) including eight moments (initial contact, maximum Ground Reaction force, initial flight, maximum back cocking, maximum height of body CG during flight, maximum height of hand throwing CG during flight, release ball, and ground contact).

Table 1. Correlation between Body COM kinematical parameters and ball velocity during Jump throwing phases in Handball.

Parameters (unit)	coordinates	Cocking phase			Acceleration phase			Following phase	
		IC	Max-GRF	IF	Max-BC	Max-CGH	Max-HH	RB	GC
Displacement (m)	x	.131	-.006	-.034	-.030	-.099	-.019	-.027	-.058
	y	-.173	.489	.710*	.524	.823**	.738*	.762*	.854**
	z	.190	-.472	-.099	-.004	.039	.295	.226	-.886-**
	R	.220	-.582	-.636-*	.309	.646*	.796**	.812**	.826**
Velocity (m/s)	x	-.204	-.231	-.077	-.081	.019	.330	-.287	-.102
	y	.680*	.776**	.838**	.807**	.892**	.656*	.588	.550
	z	-.538	-.289	.127	.542	-.018	.492	-.034	-.367
	R	.691*	.721*	.864**	.786**	.899**	.512	.734*	.696*
Acceleration (m/s^2)	x	.038	.143	-.403	.170	-.125	-.555	-.399	.186
	y	.176	.126	.120	.311	.044	-.358	.086	-.016
	z	-.339	-.108	-.034	.502	.003	-.105	-.038	.652*
	R	.074	-.116	.105	-.454	.021	.210	.152	.108

Note: Coordinates. X (medio-lateral), Y (anterior-posterior), Z (vertical), and R (resultant); Moments. IC: initial contact (end of last step); max-GRF: maximum Ground Reaction force; IF: initial flight; max-BC: maximum back cocking; max-CGH: maximum height of body CG during flight; max-HH: maximum height of hand throwing CG during flight; RB: release ball; GC: ground contact; *. Correlation is significant at *p<0.05*; **. Correlation is significant at *p<0.01*.

Table 1 indicated to a significant correlation between ball velocity and COM displacement Y at the moments (initial flight: *p<0.05*; maximum height of body CG during flight: *p<0.01*; maximum height of hand throwing CG during flight: *p<0.05*; release ball: *p<0.05*; ground contact: *p<0.01*), and COM displacement R (initial flight: *p<0.05*; maximum height of body CG during flight: *p<0.05*, maximum height of hand throwing CG during flight: *p<0.01*, release ball: *p<0.01*, ground contact: *p<0.01*).

The major finding of table 1 results was the relationship between displacement Y with ball velocity at initial flight (take-off) and emphasized the importance of this moment when evaluating jump throwing, and it can be considered a discriminate moment of jump throwing. Moreover, initial flight moment affected on next moments (Table 1).

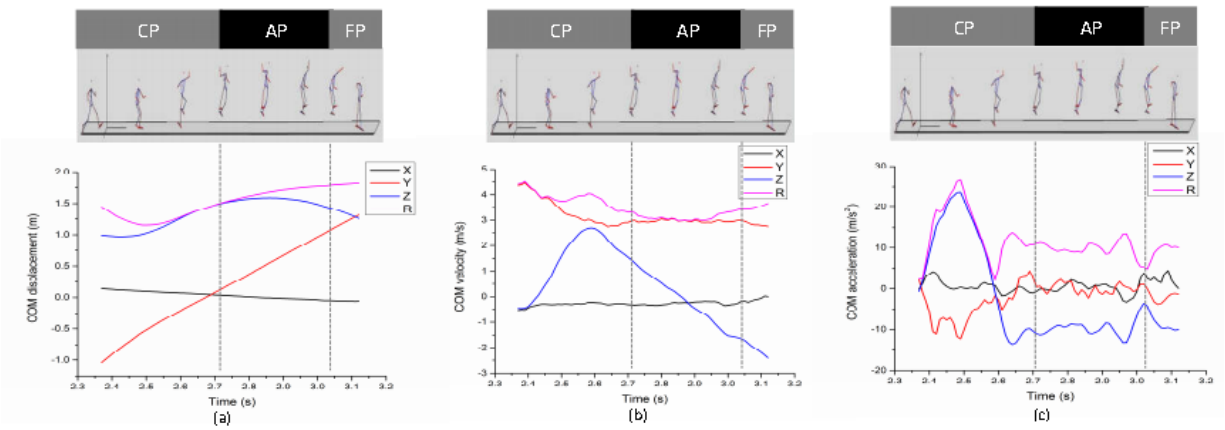

Figure 1: Body COM kinematical parameters during Jump throwing phases: (a) displacement (X, Y, Z, R); (b) velocity (X, Y, Z, R); (c) acceleration (X, Y, Z, R). Note: CP (Cocking phase); AP (Acceleration phase); FP (Following phase).

As well as the results indicated to a significant correlation between ball velocity and COM velocity Y (initial contact: $p<0.05$; maximum Ground Reaction force: $p<0.01$; initial flight: $p<0.01$, maximum back cocking: $p<0.01$; maximum height of body CG during flight: $p<0.01$; maximum height of hand throwing CG during flight: $p<0.05$), and COM velocity R (initial contact: $p<0.05$; maximum Ground Reaction force: $p<0.05$; initial flight: $p<0.01$; maximum back cocking: $p<0.01$; maximum height of body CG during flight: $p<0.01$; release ball: $p<0.05$; ground contact: $p<0.05$). In addition, a significant correlation between ball velocity and COM acceleration Z (ground contact: $p<0.05$). Consequently, COM velocity Y is one of the important parameters during jump throwing, due the gained velocity from run-up (Figure 1b), it is influencing on the performance from initial contact to the second moment before ball release. In addition, it affected on the resultant of COM velocity during the performance. Interestingly, the results showed non-significant between COM accelerations and ball velocity, except vertical velocity when ground contact after landing because the gravity.

CONCLUSION: Our findings indicated that COM kinematical parameters are very important when evaluating jump throwing performance in handball, especially displacement and velocity on movement direction (anterior-posterior). Furthermore, the cocking phase is very important as a preparation phase to acquire the velocity of the body and arm throwing. Finally, the horizontal jump more associated with ball velocity than a vertical jump, although many situations in the game required the vertical jump. Thus, we recommend the coaches to focus to apply these conclusions to training programs, and for evaluating the performance level of handball players.

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