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Relationship between kinematic parameters of standing throw and ball velocity of female handball players

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Abstract
Purpose: The standing throw is the most applied throwing technique in team handball (Wagner *et al*., 2008); therefore, the purpose of our study was: to establish the relationships between kinematic parameters and ball velocity at release (shooting performance), a key performance factor.
Methods: Overall, 10 junior female state level (west Bengal) players from the Guskara College handball coaching camp were analyzed by using two standard camcorders. Ball velocity was assessed in standing throw (St) from 7 m penalty spot. Kinovea 0.8.27 motion analysis software was used to access the kinematic data. IBM SPSS Statistics 25 was used for statistical calculation. Pearson correlation coefficient was used to determine the correlation between variables. The level of Significance was set at $p<0.05$.
Results: A high degree linear positive association has been found in stride length (r = 0.665*), relative Centre of Gravity height at ball release (r = 0.701*), angle of knee joint of the front foot (r = 0.655*), and the hip angle at ball release (r = 0.714*) with the initial ball velocity of standing throw. Whereas a negative association has been observed in the following parameters i.e., ball holding duration, the relative height of the ball at release, and Angle of wrist joint at ball release. Elite level junior female handball players show an average ball velocity i.e., 12.75 m/s with a flexed hip joint where the observed mean hip angle was 143.4^0. The relative C of G height (mean 94.02 ± 5.59 cm) from the ground at ball release has a great impact on initial ball velocity that ultimately results in throwing performance in handball. Due to the high release point, a negative association was found with throwing performance. For greater ball speed an athlete requires a hyperextended wrist angle with a moderate ball holding time, prior to releasing too much swing of ball throwing arm or too less swing leads negatively to the throwing performance.
Conclusions: The initial ball velocity was the most important in handball shooting performance in which players need to be using the best angles during the performance, particularly the elbow, hip, knee, and wrist joint angle. On the other hand, the body's C of G height at release, stride length, and maximum release height of the ball should have a positive impact and association to achieve the best result from the game.

Keywords: Biomechanics, kinematic analysis, ball velocity, throwing accuracy

Introduction
In Olympic Games, team handball is played at a professional level between several countries. Recently, handball has received increased attention in research studies, especially in biomechanics (Plummer, H. A.; Oliver, G.D. 2017) [9]. In order to determine the essential processes for developing handball players, kinematic factors contribute to the ball's velocity. Between the top and lesser performance levels, Wagner, Buchecker, Von Duvillard, and Muller (2010) [22] observed a substantial difference in ball velocity, body height, and weight. Men's field handball was first presented at the 1936 Summer Olympic Games in Berlin, but it was quickly abandoned. Field handball was a showcase sport at the 1952 Olympic games. Men's (indoor) handball was inaugurated in the 1972 Summer Olympics in Munich, Germany. At the 1976 Summer Olympic Games in Montreal, women's handball was presented for the first time.
"Biomechanics measurement allows for precise, quantifiable examination of technical features, which then becomes a benchmark of a training program and seems to be a factor in effective training design, particularly if it concerns to detect the degree of performance expertise and assessing it as part of an athlete's personal growth process, as well as adopting

Kinesiological operators and modeling methodical methods" (Mejovšek, *et al*., 1997).

Other research suggests that anthropometric measurements are poor predictors of scores on fundamental and particular motor ability tests in handball, a sport that involves agility, explosive lower-limb strength, accuracy, movement speed, and handball-specific abilities (Visnapuu M, Jürimäe t. 2009) [20]. In the jump throw, however, team handball players who are taller and heavier had faster ball release speeds, and increasing trunk flexion and rotation angular velocity enhances ball release speed. Srhoj V, Rogulj N, Papic V, Foretic N, Cavala M. (2012) [11] indicated that high overarm throw speeds need both anthropometrics and appropriate technique.

Despite the fact that there was a plethora of research linking overarm throw speed to various anthropometric, technical, or performance characteristics, the authors were unaware of any studies pertaining to overarm throw velocity for handball players. As a result, the scholar has intended to carry out this study in order to determine the relationship between kinematic parameters and ball velocity at standing throw in elite female young handball players.

Purpose of the study

The basic aim of this study was, to analyze kinematic parameters at the time a standing shot had been performed by the junior female handball players and to investigate the degree of association of these parameters with ball velocity.

Material and methods

Subjects

Overall, 10 professional state-level handball female players (mean age: 17.7 ± 1.25 years, range: 16-20 years; body weight: 52.8 ± 2.04 kg; body height: 164 ± 4.08 cm). The players competed in the Inter-University East Zone Handball Championship and the State Inter-Collegiate Handball Tournament. All subjects had no pain or disabilities in the upper or lower body.

Procedures

Data collection was conducted with the permission of the coach and players (regular trainee at Guskara Mahavidyalaya handball ground). Before the data collection players were informed about the tests to be performed as they have to go for a standing throw to the goal from the 7 m penalty spot. To reduce the effects of exhaustion, all participants performed three trials with a three-minute pause in between. The video graphics data were gathered on Wednesday 17th Nov 2021 morning. The motion analysis package Kinovea (version 0.8.27) was then used to inspect it.

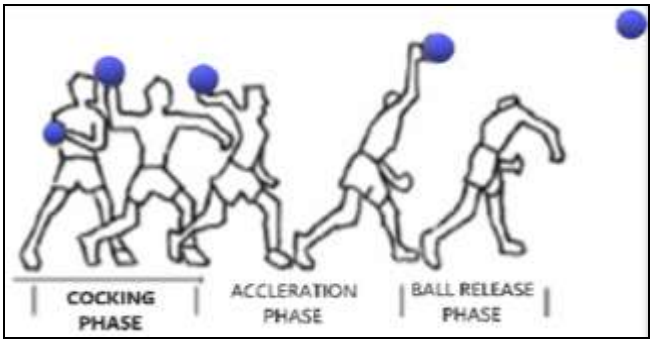

Fig 1: Different phases of standing throw in handball

Table 1: List of Kinematic variables

	Sl. No.	Kinematic variables	Measuring unit
Ball Release Phase	1	Initial ball velocity	m/sec
	2	Stride length	cm
	3	Duration of holding the ball with one hand till the throw	Sec
	4	Knee angel of Front leg	ɵ
	5	Elbow angel of throwing arm	ɵ
	6	Hip angle	ɵ
	7	Height of the body's center of gravity	cm
	8	Relative ball height	cm

All measurements of anthropometric parameters were collected during the training session. The anthropometric properties were analyzed as per the procedure of the International Society for the Advancement of Kinanthropometry (ISAK). All players were measured before training season with light clothing, and barefoot. Basic measurements (height, body mass) were determined with a thin line tape and weighing machine. A qualified ISAK level 1 anthropometrist determined all anthropometric parameters.

Video data acquisition for kinematic analysis

Acquisition of the video recordings for kinematic analysis was made by two camcorders (Nikon B700) with the frequency of 60 fps. Camcorders set up is explained in figure no 1.

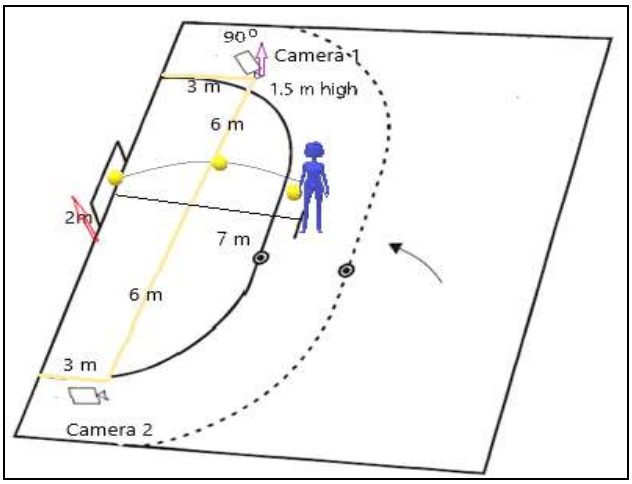

Fig 2: Outline of the video recoding

Before each test, players have performed a 15-minute warm-up session, later they were asked to throw a ball at maximum velocity in standing throw at the 7 m line without displacement (St). Each throw was performed with no intervention of a goalkeeper.

Statistical analysis

For descriptive analysis, mean and standard deviation values were employed. Bivariate Pearson's product-moment correlation coefficient (r) with 95% confidence (p<0.05) was applied to determine relationships between dependent and independent variables. All statistical analyses were performed with the use of SPSS 25 statistical software.

Results and discussion

Table 2: Depiction of Mean values (kinematic parameters)

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Initial velocity (m/sec)	10	11.32	14.45	12.75	0.91
Stride length (cm)	10	61.56	84.79	76.66	7.56
Duration of holding the ball with one hand till the throw (sec)	10	0.98	1.63	1.32	0.21
Height of the body's center of gravity at the time of throw (cm)	10	81.23	100.15	94.02	5.59
Relative height of the ball at release (cm)	10	158.07	187.12	169.57	8.52
Angle of knee joint at ball release (^{0})	10	137.00	157.00	147.40	7.06
Angle of elbow joint at ball release (^{0})	10	58.00	109.00	95.20	16.79
Angle of wrist joint at ball release (^{0})	10	158.00	222.00	196.10	19.60
Angle of hip joint at ball release (^{0})	10	131.00	149.00	143.40	5.10

Table 3: Coefficient of correlation among the initial ball velocity (at release) and kinematic variables

Correlations									
	Initial velocity (m/sec)	**Stride length (cm)**	**Duration of holding the ball with one hand till the throw (sec)**	**Height of the body's center of gravity at the time of throw (cm)**	**Relative height of the ball at release (cm)**	**Angle of knee joint at ball release (^{0})**	**Angle of elbow joint at ball release (^{0})**	**Angle of wrist joint at ball release (^{0})**	**Angle of hip joint at ball release (^{0})**
Initial velocity (m/sec)	1	.665*	-0.195	.701*	-0.286	.655*	0.018	-0.115	.714*
Stride length (cm)	.665*	1	0.414	0.467	-0.003	0.513	0.371	-0.193	0.592
Duration of holding the ball with one hand till the throw (sec)	-0.195	0.414	1	0.267	0.334	0.290	0.585	0.356	0.001
Height of the body's center of gravity at the time of throw	.701*	0.467	0.267	1	0.097	.769**	0.219	0.400	.716*

(cm)									
Relative height of the ball at release (cm)	-0.286	-0.003	0.334	0.097	1	-0.122	0.409	-0.122	0.156
Angle of knee joint at ball release (^{0})	.655*	0.513	0.290	.769**	-0.122	1	0.457	0.551	0.346
Angle of elbow joint at ball release (^{0})	0.018	0.371	0.585	0.219	0.409	0.457	1	0.182	-0.038
Angle of wrist joint at ball release (^{0})	-0.115	-0.193	0.356	0.400	-0.122	0.551	0.182	1	-0.130
Angle of hip joint at ball release (^{0})	.714*	0.592	0.001	.716*	0.156	0.346	-0.038	-0.130	1
N	10	10	10	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed) r value at 8 df = 0.632

**. Correlation is significant at the 0.01 level (2-tailed).

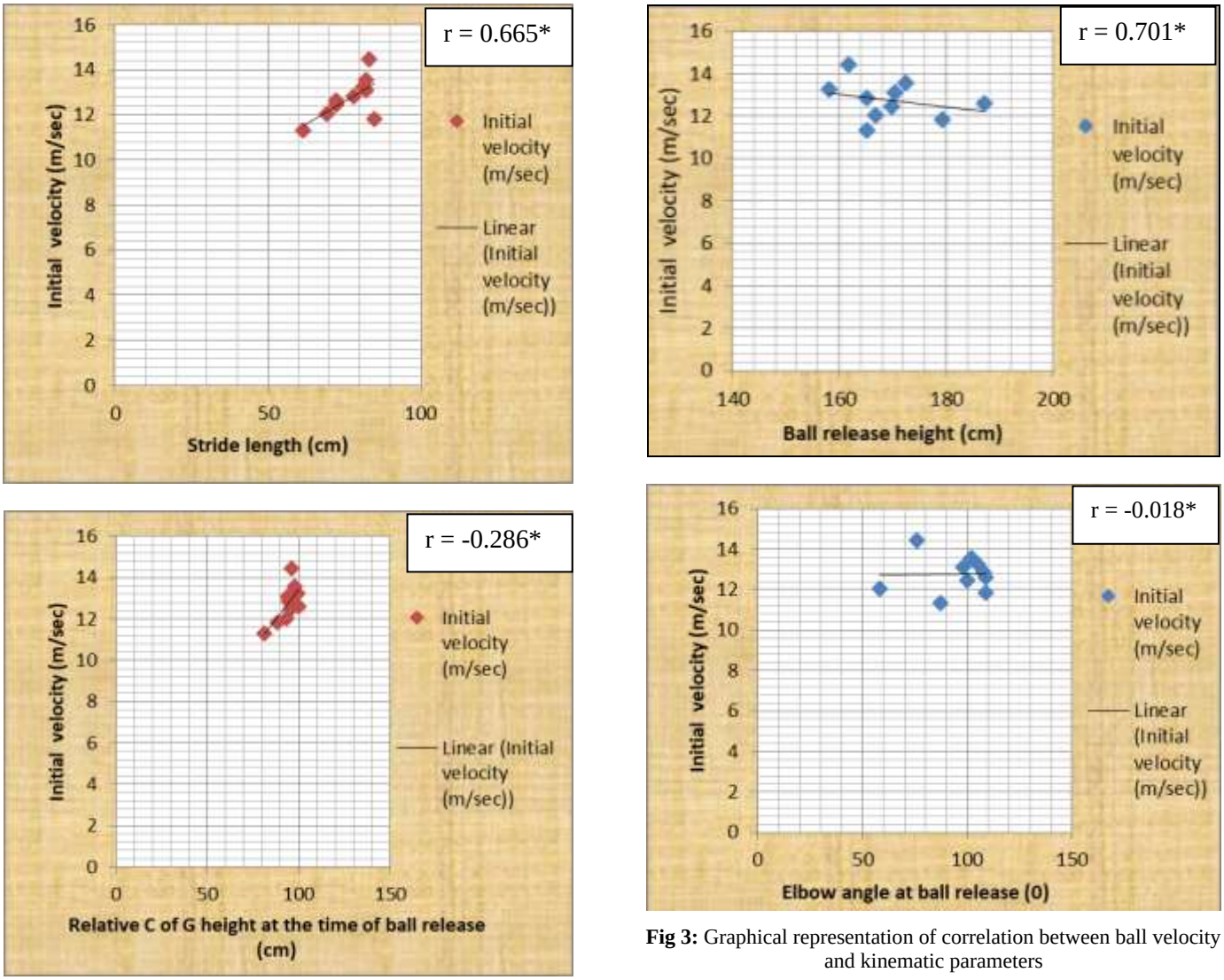

Fig 3: Graphical representation of correlation between ball velocity and kinematic parameters

From the results of the study, a high degree positive association has been found in stride length (*), relative Center of Gravity height at ball release (r = 0.701*), angle of knee joint of the front foot (r = 0.655*), and the hip angle at ball release (r = 0.714*) with the initial ball velocity of standing throw. Whereas a negative association has been observed in the following parameters i.e., ball holding duration, the relative height of the ball at release, and Angle of wrist joint at ball release.

Elite level junior female handball players showed an average ball velocity i.e., 12.75 m/s with a flexed hip joint where the observed mean hip angle was 143.4°. The relative C of G height (mean 94.02 ± 5.59 cm) from the ground at ball release has a great impact on initial ball velocity that ultimately results in throwing performance in handball. Due to the high release point, a negative association was found with throwing performance. For greater ball speed an athlete requires a hyperextended wrist angle with a moderate ball holding time, before releasing too much swing of ball throwing arm or too less swing leads negatively to the throwing performance.

Many specialists were interested in the investigation of kinematic characteristics when it came to throwing and aiming at a goal, i.e., the phase of releasing the ball or other items in various sports. Individual examination of throws in other sports, such as baseball (Escamilla, 1998) [5], water polo (Feltner, & Taylor, 1997) [6], handball (Coleman, Benham, & Northcott, 1993) [3], and javelin throw (Best, Bartlett, & Morriss, 1993) [2], revealed comparable principles of throwing (proximal-to-distal segmental sequence). Bergün, 2008; Van Den Tillar, 2005 [1, 13] conducted a follow-up study that included a comparison of the observed kinematic characteristics in those fields. The study of kinematic parameters in handball was primarily focused on the analysis of non-jumping throws, and it revealed linear velocities of various body segments (Tuma & Zahalka, 1997; Jöris *et al*., 1985; Van Den Tillar & Ettema, 2003; Fradet *et al*., 2004) [12, 7, 17] as well as angular velocities of certain body joints at the time of the throw (Tuma & Zahalka, Van Den Tillar & Ettema, 2004; Fradet *et al*. 2004) [12]. The results of our study are in agreement with other studies in team-handball (Van Den Tillaar and Ettema, 2004; 2007; Wagner and Müller, 2008) [15, 19, 21] regarding the maximal initial velocities at release. Maximal elbow extension and wrist flexion and hip flexion of our elite, as well as low-level players, were higher than those found by Van Den Tillaar and Ettema (2007) [17] elbow: 143° ± 24.6°; wrist: 56.8° ± 19.3°) for the standing throw in team-handball and lower than those found by Wagner and Müller (2008) [21]. A world-class team-handball player reaches a maximal angular velocity of shoulder internal rotation of 81.3° ± 12°/s and a ball release speed of 25.1 ± 0.8 m/s during a standing throw.

Conclusions

Based on the main findings from this study, the stride length, relative C of G distance were positively correlated with ball velocity during the release phase as that accelerates the arm throwing. The maximum ball height from the ground was negatively associated that hindered achieving the highest ball velocity. Furthermore, the results indicated that the change in angular variables of the hip joint is greater than those of the elbow and wrist. As a result, when analyzing the performance level of handball players, we recommend that coaches focus on boosting their players' horizontal mobility in training programs to permit forward movement during the landing. Also, we recommend that coaches use special power and reaction time exercises to reduce the dominant foot contact time at release before throwing the ball. This would allow the player to achieve greater acceleration before the ball release and keep the maximum velocity of the ball while throwing performance.

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