3D KINEMATIC ANALYSIS OF OVERARM MOVEMENTS FOR DIFFERENT SPORTS

Meriç Bergün[1], Aydin Menşure[1], Çolak Tuncay[2], Özbek Aydın[2], Bulgan Çiğdem[3]

[1]Kocaeli University, School of Karamursel Physical Education and Sport, Kocaeli, Turkey
[2]Kocaeli University, School of Medicine, Department of Anatomy, Kocaeli, Turkey
[3]Loughborough University, Sports Biomechanics, Leicestershire, UK

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Abstract:

The aim of this study was to compare the kinematics of the overarm throw for different sports. Eleven elite female handball players and nine elite female volleyball players were selected as subjects for the study. Arm and forearm segment movement in the backswing and acceleration phases of players performing the volleyball spike and the handball jump shot were evaluated. Video data were captured using two Sony 50Hz cameras and were digitized and analyzed using Simi Motion Analysis 5.5 program. In the backswing phase, there were significant differences in the angular width, velocity and acceleration between the volleyball players and handball players on the transverse, vertical, and sagittal planes of the motions ($p<.01$). In the acceleration phase, the statistically significant difference was found in the angular width of the arm segment motion on the transverse plane ($p<.05$). On the sagittal plane, the significant difference was found in the angular width, velocity, and acceleration of the arm motions between the volleyball and handball players ($p<.05$). These results suggest that volleyball players use vertical flexion more frequently, thus increasing the time to gain velocity. Handball players transfer the velocity used in horizontal flexion to the vertical flexion in a short period of time.

Key words: *kinematics, overarm throw, handball, volleyball*

Introduction

To achieve perfection, kinesiological and biomechanical analyses need to be undertaken to understand the affects of the existing techniques on movement, and accordingly new techniques need to be developed.

Overarm is one of the most important movements in most sports such as volleyball, handball, baseball, tennis, javelin throw, and shot put. In some of these sports, the outcome of the overarm movement is either a throw or a hit. Jump shot executed by handball players and javelin throw are examples of overarm throws, while a tennis service and spikes in volleyball are examples of overarm hits. Although the movements seem to be similar, the results differ for the simple fact that one is a throw and the other is a hit.

Velocity of throw is a major factor for overarm movement in branches such as baseball, handball, javelin throw, and water polo (Van Den Tillaar, 2004). Maximal isometric force affects the velocity in a positive way (Van den Tillaar & Ettema, 2003). As precision of hitting the mark and the weight of the ball increase, throwing velocity will decrease (Van den Tillaar & Ettema, 2004a; Van den Tillaar & Ettema, 2003; Van den Tillaar & Ettema, 2004b).

Joint kinematics is also very important in terms of throwing velocity. For example, research carried out by Takahashi, Ae, Fujii, Shimada, and Ozaki (2000) showed that wrist and finger flexibility were very important for velocity and acceleration of the ball before release. There are also studies that show angular width velocity affects the acceleration of the ball (Coleman, 1997; Coleman, Benham, & Northcott, 1993).

To attain the best results, the athlete must employ the correct technique. This study was aimed at demonstrating two different overarm movements, one in throws and one in hits, by investigating back swing and acceleration phases as well as kinematic analysis and technical differences.

Material and Methods

Participants

Nine female volleyball players (age: 24±4yrs, height: 174.45±4.50 cm, weight: 68.03±5.32 kg) from the women's volleyball super league and eleven female handball players (age: 20±2yrs, height: 174.63±7.28 cm, weight: 65.81±5.21 kg) from the national women handball team joined this study. All the players in this study were right-handed. They had no history of injury within the last year. Volleyball passers and handball goalkeepers were not analyzed here. The measurements of both teams were conducted in an Olympic hall.

Procedures

The players were allowed to have as many trials as they wanted after they had warmed up. Reflective markers with 3cm in diameter, were placed on the ulnar styloid, lateral humeral epicondyle, and lateral superior tip of the acromions. The arm segment was made up by putting together acromion and a humeral epicondyle, and the forearm segment was made up by putting together humeral epicondyle and ulnar styloid.

Recording sessions were done by 2 Sony Trv330e 50hz camcorders, technically smilar (Baly, Favier, & Durey., 2001; Coleman, Benham, & Northcott, 1993; Escamilla, Fleisig, Barrentine, Zheng, & Andrews, 1998; Yan, Hinrichs, Payne, & Thomas, 2000; Feltner & Taylor, 1997; Wit & Eliasz, 1998). Both camcorders were placed at a 90º angle where they had a view of each other's movement range (Figure 1) as this method had been previously used in many similar experiments, relevant to our study (Best, Bartlett, & Morriss, 1993; Bahamonde, 2000; Miller & Bartlett, 1996; Roberton & Konczak, 2001). For calibration, Direct Linear Transformation technique was used (Abdel-Aziz & Karara, 1971; Shapiro, 1978, Taborsky, Martin, & Frantisek, 1999). The calibration space was 2 x 2.50x 2m, and 8 calibration points were used (Figure 1).

The volleyball players were asked to spike and the handball players to shoot from a jump. The spikes were performed in area 4 by the volleyball players. Only one passer gave passes to the volleyballers. The jump shots were done by the handball players from the goal area line.

Each player's movement was repeated 5 times and each repetition was recorded. There were breaks of 60-90 seconds between each movement. The data were then transferred to a computer using SIMI motion program (Version 5.5, Reality Motion System, Germany). Determinations of the movement were analyzed by the coach, as had been performed in earlier studies (Werner, Gill, Murray, Cook, & Hawkins, 2001; Sakurai, Ikegami, Okamoto, Yabe, & Toyoshima, 1993; Elliott, Marsh, & Blansky, 1986).

For the arm and forearm segments, horizontal flexion and horizontal extension on XY axis transverse plane, flexion and extension on YZ axis, sagittal plane, abduction and adduction on XZ axis, and vertical plane values were studied.

For each of these planes, angle (θ) with degree (º), angular velocity (w) with degree/second (º/s), angular acceleration (α) with degree/second2 (º/s^2) were evaluated.

Movement Phases

In our research, only acceleration and backswing phases related to upper extremity were evaluated because the other phases do not directly involve the segments of concern in this motion. This motion was evaluated at different phases in earlier studies (Taborsky, et al., 1999; Zvonarek & Hraski, 1996; Yan, et al., 2000; Huang, Liu, & Sheu, 1998; Huang, Liu, Lim, & Sheu, 1999). Some of these studies included only two phases as did our study (Chung, Shin, & Choi, 1990; Sekine, Toyokawa, Ae, Fjii, & Shimada, 1999).

For both sports, acceleration phase has been defined as the movement spanning from the beginning of the backward motion of the arm to the maximum external rotation of the shoulder (Chung, et al., 1990). The acceleration phase started when the backswing phase finished and went on until the shot (Figures 2 and 3).

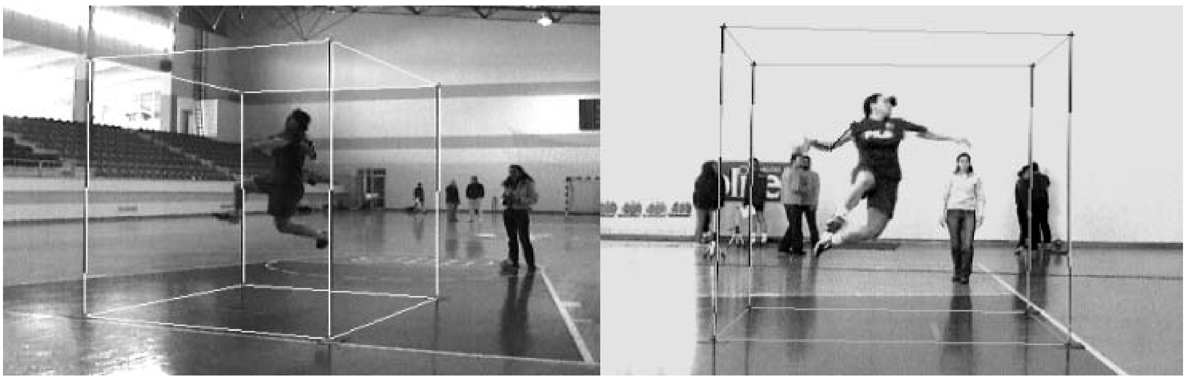

Figure 1. Cameras' angles and calibration cube.

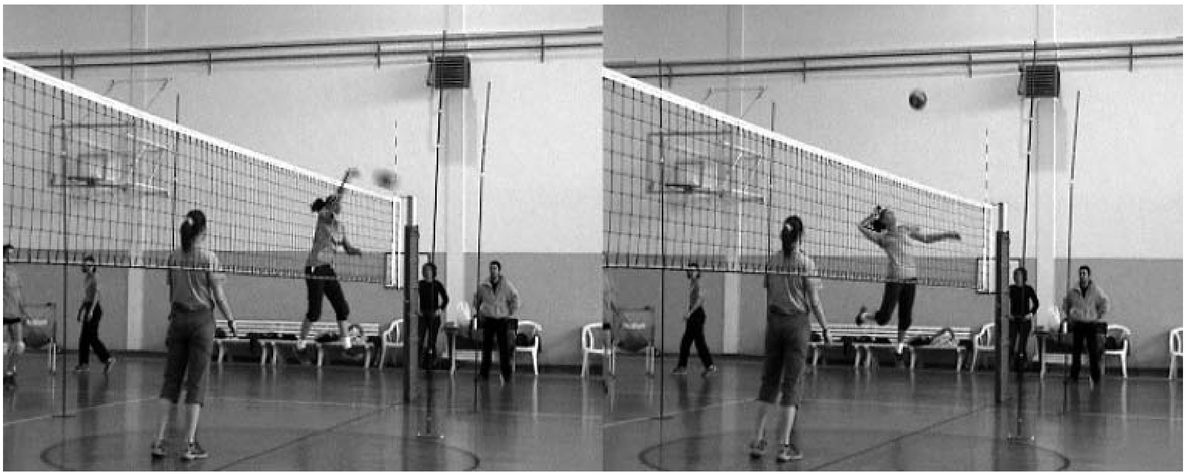

Figure 2. Backswing and acceleration phase of a volleyball spike.

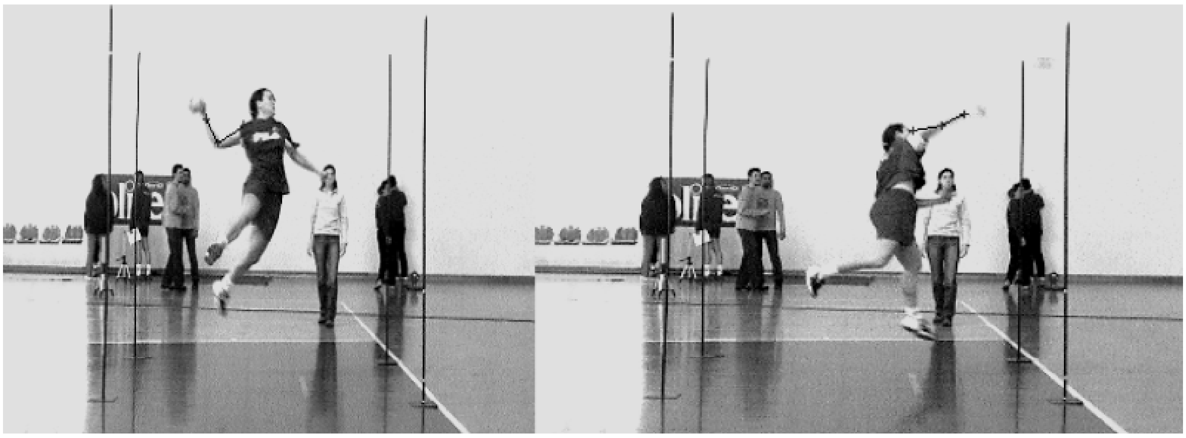

Figure 3. Backswing and acceleration phase of a jump shot in handball.

Data Processing

The results are presented as means±SD. Differences between the groups were calculated using a nonparametric test for independent samples (Mann-Whitney U). The SPSS package for personal computer was used for the statistical analyses. A p-value less than .05 was considered significant.

Results

In the backswing phase, statistically significant differences were found between the volleyball players and the handball players in terms of angle, angular velocity, and angular acceleration on all the planes ($p<.05$).

In the acceleration phase, the statistically significant differences were found between the volleyball players and the handball players in the angle on the transverse plane, in angular velocity on the vertical plane, and in angle, angular velocity, and angular acceleration on the sagittal plane ($p<.05$) (Table 1).

Table 1. Angle, angular velocity, angular accelaration of the arm and forearm

				SEGMENT OF THE ARM				SEGMENT OF THE FOREARM			
			N	BACKSWING		ACCELERATION		BACKSWING		ACCELERATION	
Transverse plane	XYθ (°)	Volleyball	9	-6.2 ± 2.4	**.001****	-36.7 ± 2.9	**.001****	-47.3 ± 1.6	**.001****	-28.3 ± 3.6	**.05***
		Handball	11	35.7± 1.4		-22.1 ± 1.4		-9.6 ± 2.8		-48.5 ± 2.0	
	XYW (°/s)	Volleyball	9	-109.9 ± 28.9	**.001****	-112.5 ± 46.9	.13	71.1 ± 30.3	**.001****	-83.0 ± 63.3	.07
		Handball	11	-189.1 ± 13..3		-137.8 ± 30.3		-289.9 ± 21.3		108.3 ± 38.4	
	XYα (°/s^2)	Volleyball	9	1331.2 ± 486.2	**.001****	2997.4 ± 652.3	.06	1974.3 ± 522.8	**.03***	-1595.0 ± 1130.3	**.02***
		Handball	11	-976.9 ± 206.4		4007.7 ± 293.4		447.7 ± 414.2		3562.7 ± 848.2	
Vertical plane	XZθ (°)	Volleyball	9	-24.1 ± 3.1	**.001****	-11.3 ± 4.2	.19	27.1 ± 1.8	**.001****	-8.1 ± 3.6	.37
		Handball	11	-48.1 ± 1.3		-12.7 ± 4.7		-8.0 ± 1.6		-16.3 ± 2.7	
	XZW (°/s)	Volleyball	9	-370.5 ± 24.6	**.71**	444.0 ± 35.7	**.001****	2.2 ± 23.7	**.03***	13.9 ± 68.5	**.001****
		Handball	11	-141.1 ± 14.2		677.0 ± 27.3		-113.8 ± 16.9		300.7 ± 56.3	
	XZα (°/s^2)	Volleyball	9	2719.3 ± 465.0	**.56**	1210.7 ± 654.8	.69	-1852.1 ± 419.8	**.001****	5180.1 ± 1033.9	.15
		Handball	11	1179.6 ± 275.6		1708.5 ± 740.3		1112.3 ± 309.2		4973.9 ± 693.3	
Sagital plane	YZθ (°)	Volleyball	9	44.3 ± 2.2	**.02***	21.0 ± 1.2	**.001****	-.4 ± 2.9	**.001****	-25.9 ± 2.9	**.05***
		Handball	11	3.5 ± 1.6		33.4 ± 2.1		46.8 ± 2.2		-19.4 ± 2.2	
	YZW (°/s)	Volleyball	9	-106.6 ± 31.2	**.05***	-30.0 ± 19.1	**.05***	-142.3 ± 39.2	**.05***	75.8 ± 49.6	**.05***
		Handball	11	-12.6 ± 21.1		102.2 ± 38.3		-161.1 ± 34.3		23.2 ± 46.4	
	Yzα (°/s^2)	Volleyball	9	-1391.0 ± 603.7	**.04***	-111.24 ± 322.6	**.001****	-912.0 ± 718.7	**.001****	2036.8 ± 832.6	**.04***
		Handball	11	1274.2 ± 313.9		-3656.7 ± 516.8		-2984.4 ± 401.5		3767.6 ± 720.5	

* p<.05
** p<.01

Discussion and conclusion

Literature reveals several studies on volleyball and handball movement analysis; however, there are no studies comparing the kinematics of volleyball and handball. In this study, overarm movements in both sports were evaluated in two phases, backswing and acceleration, in three dimensions.

In the backswing phase, the arm segment movements of the volleyball players and handball players significantly differed on the transverse plane in terms of angular width, angular velocity, and acceleration (p<.01). Extension movement of volleyball players in the backswing phase was more vertical, whereas in handball players it was more horizontal. Therefore, handball players naturally have more arm movement space and angle. There were significant statistical differences in the angular width, velocity, and acceleration between the volleyball and the handball players on the transverse plane of the motions (p<.01). While angular width and acceleration levels were higher in volleyball players' performance, velocity was higher in handball players. Velocity and acceleration in the arm segment were parallel to the forearm segment.

In the vertical plane, the movement angles of the arm segment of the handball and the volleyball players differed significantly (xz) (p<.01). Although the backswing phase of the handball players' movement had a higher angular value than the one of the volleyball players, it did not provide any advantages in terms of angular velocity. On the vertical plane, there were the statistically significant differences in the values of angular width, velocity, and acceleration of forearm between the two groups of players (p<.05). While the volleyball players' angular width and acceleration values were higher than those of the handball players, the velocity values of the handball players were higher than those of the volleyball players (p<.05).

Similarly, on the sagittal plane, the statistically significant differences were detected between volleyball players' and handball players' movement in terms of angular width, velocity and acceleration of the arm segment (yz) (p<.05). These results were expected because volleyball players perform motions more into the sagittal plane. Compared to the volleyball players, the handball players had higher values of angular width, velocity, and acceleration of the forearm motion on the sagittal plane (p<.05).

In the acceleration phase, the angular width of the volleyball players was significantly higher than that of the handball players during the arm segment motion on the transverse plane (xy) (p<.05). On the other hand, the angular width of the forearm segment of the handball players was significantly higher than that of the volleyball players on the transverse plane (p<.05). Although there were no statistical differences in the velocity values, the angular value was higher in the transverse plane. Motions in the transverse plane define the horizontal motion of the arm and forearm segments. Although the total rotation movement has not been measured in this research, the movement was also performed in the transverse plane. The results showed that handball players had higher values for the motions in the transverse plane. This is related to the fact that technical specification of spike and jump shot in volleyball and handball, respectively, are of the same value, because external rotation is the most frequently used movement in the backswing phase of the overarm movement, whereas internal rotation is usually used within velocity and acceleration phases (Wells, 1966).

The handball players had higher velocity values than volleyball players did in terms of arm movements on the vertical plane (xz) ($p<.05$). There were significant differences between the values for the angular velocity of the forearm movements of the handball players and volleyball players on the vertical plane ($p<.05$). Nevertheless, there were no differences in terms of angular width and acceleration. The studies show that the angular velocity affects the ball's velocity, which suggests that in order to increase the velocity, the angular velocity of handball players should be higher (Coleman, 1997; Coleman, Benham, & Northcott, 1993). The angular velocity of handball players in the backswing phase causes higher velocity.

There were also differences between the angular width, angular velocity, and acceleration of the arm movements of the handball players in the sagittal plane (yz). Although the sagittal plane is used more frequently and movements in this plane have higher angular value in volleyball players, the handball players had a higher value in the acceleration phase of the same plane. Instant switching from horizontal flexion to the vertical flexion creates higher acceleration in handball players than in volleyball players. This is because volleyball players use vertical flexion more often to gain velocity, while handball players transfer the velocity used in the horizontal flexion on to the vertical flexion. In the sagittal plane, the handball players had higher values for all movements of the forearm ($p>.05$). Flexion and extension in the sagittal plane are the only movements that belong to the forearm segment, while in other axes, the forearm segment moves with shoulder movements. For this reason, those handball players who have high arm segment movements also have high values.

Although there were differences between jump shot and spike, very similar movements of overarm movement technique, performed by volleyball players and handball players, spikes were executed within appropriate forms of the overarm hitting technique and jump shot with the proper overarm throwing technique. It is, therefore, thought to be the main reason for the differences. However, some important results were found in order to create high acceleration with the appropriate technique. Particularly in handball players, it was proven that higher acceleration was produced when players instantly switched from horizontal flexion to vertical flexion.

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Correspondence to:
Bergün Meriç,Ph.D.
Kocaeli Universitesi Karamürsel Beden Eğitimi ve Spor Yüksekokulu
41500, Dereköy/Karamürsel, Kocaeli, Turkey
Phone: + 90 262 45 43 452
Fax: + 90 262 45 43 453
E-mail: bergunmeric@gmail.com

TRODIMENZIONALNA KINEMATIČKA ANALIZA ZAMAHA RUKOM IZNAD GLAVE U RAZLIČITIM SPORTOVIMA

Sažetak

Za poboljšanje sportske uspješnosti nije dovoljno unapređivati samo kondicijske sposobnosti i tehničko-taktička znanja. Moraju se provesti i kineziološke i biomehničke analize kretanja kako bismo razumjeli učinke postojećih tehnika kretanja te se, u skladu s rezultatima tih analiza, moraju razvijati nove i učinkovitije tehnike kretanja. Cilj ovog rada bila je usporedba kinematičkih analiza bacačkih, odnosno udaračkih tehnika koje se izvode u različitim sportovima zamahom ruke iznad glave.

Devet odbojkašica iz ženske odbojkaške superlige (starih 24±4 godine, visokih 174,45±4,5 cm, teških 68,03±5,32 kg) i 11 rukometašica, članica nacionalne vrste (starih 20±2 godine, visokih 174,63±7,28 cm, teških 65,81±5,21 kg) sudjelovalo je u istraživanju. Odbojkašice-dizačice lopte i rukometne vratarice nisu sudjelovale u istraživanju. Nakon zagrijavanja, ispitanicama su na stiloidni nastavak lakatne kosti, lateralni epikondil nadlaktične kosti i lateralni gornji vrh akromiona postavljeni reflektirajući markeri dijametra 3 centimetra. Za snimanje su korištene dvije Sonyjeve kamere, model Trv330e i frekvencije 50Hz. Kamere su bile postavljene pod kutom od 90° kako bi mogle snimiti cijelo područje kretanja ispitanica. Za kalibraciju sustava korištena je tehnika izravne linearne transformacije. Mjere kalibracijskog prostora bile su 2 x 2,5 x 2 m sa 8 kalibracijskih točaka. Odbojkašice su izvodile smečeve, a rukometašice skok šutove na gol. Smečevi su izvođeni iz polja 4 na odbojkaškom terenu, a skok šutovi s linije vratarova prostora.

Svaka ispitanica 5 puta je izvela zadani element i svaki je bio snimljen. Snimljeni materijal prenesen je u računalo, a pokušaji su za kasniju analizu bili selektirani pomoću SIMI kretnog programa (verzija 5,5, Reality Motion System, Njemačka).

Analizirane su kretnje segmenata ruke i podlaktice u fazi zamaha unatrag iznad glave i fazi akceleracije kod odbojkaškog smeča i rukometnog skok šuta. Izračunati su parametri u svim ravninama: kut (θ) u stupnjevima (°), kutna brzina (w) u stupnjevima u sekundi (°/s), kutno ubrzanje (α) u stupnjevima u sekundi na kvadrat (°/s²).

Razlike između grupa izračunate su korištenjem neparametrijskog testa za nezavisne uzorke (Mann Whitney–U).

U fazi gornjeg stražnjeg zamaha utvrđene su statistički značajne razlike u veličini kuta, brzini i ubrzanju između odbojkašica i rukometašica u transverzalnoj, vertikalnoj i sagitalnoj ravnini ($p<,01$).

U fazi ubrzanja utvrđene su statistički značajne razlike u veličini kuta kod pokreta segmenata ruke u transverzalnoj ravnini ($p<,05$). U sagitalnoj ravnini utvrđeno je da rukometašice postižu statistički značajno veće kutne vrijednosti, brzinu i ubrzanje pri kretnjama ruke u odnosu na odbojkašice ($p<,05$). Razlike u tim parametrima vjerojatno su posljedica činjenice da odbojkašice kod smečiranja izvode veću vertikalnu fleksiju, koja povećava vrijeme koje je potrebno da se postigne odgovarajuća brzina ruke. Rukometašice, pak, pri izvođenju rukometnog skok šuta u vrlo kratkom vremenu prenose brzinu iz horizontalne ravnine u vertikalnu ravninu.