THE EFFECT OF SHOOTING RANGE ON THE DYNAMICS OF LIMBS ANGULAR VELOCITIES OF THE BASKETBALL SHOT

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Abstract:

The aim of our research was to describe the joint angular velocities of young basketball players (U16) during their performance of jump shots and to find out what was the effect of increasing shooting range on these velocities. Our sample included 14 players that performed the function of guards. Their average age (±SD) was 15.43±0.51 years. The analysis contemplated 370 field goals, which were performed from three different distances (3.75 m, 5.25 m and 6.75 m) perpendicular to the hoop board. The measurements were performed using an Xsens MVN inertial suit. The results showed that the maximum angular velocity in the shoulder and elbow joint became greater with the increase of shooting range. In the throw from the shortest distance, the segments were integrated into the movement of the shooting arm according to the proximal-distal principle. The temporal sequences of maxima velocities in legs were preserved in throws from all the three distances. The findings are important for young basketball players and their coaches. They have to be aware of the needed adjustments to the techniques of throws from various ranges and they must take them into account when practicing.

Key words: *jump shot, cadets, guards, proximal-distal principle*

Introduction

A jump shot is a complex and technically demanding movement pattern in which players throw the ball to the hoop while being up in the air. Accuracy of a jump shot does not depend on a single determinant, but on a combination of various factors (Okubo & Hubbard, 2015; Rojas, Cepero, Onä, & Gutierrez, 2000; Satti, 2004). Therefore, we need to ensure the optimal conditions at the time of ball release if we wish to complete an efficient (accurate) shot. The most important aspects of an efficient throw are the release height, release velocity, and the angle of release (Brancazio, 1981; Miller & Bartlett, 1996). All three parameters further depend on the distance of the jump shot performance from the hoop (Karalejić & Jakovljević, 2008). It is generally established that the angle of the release (Miller & Bartlett, 1996; Okazaki & Rodacki, 2012; Satern, 1993) and the ball release height (Okazaki & Rodacki, 2012) are decreasing as the distance is increasing, while the release velocity is increasing (Miller & Bartlett, 1996). Consequently, the jump shot movement pattern changes as well.

It is presumed that if the release velocity of the ball is increasing with the distance, then the joint angular velocity at the time of release is increasing as well. This increase has shown itself in the shoulder joint (flexion) and the elbow joint (extension) (Miller & Bartlett, 1996; Okazaki & Rodacki, 2012; Satern, 1993). Some studies even show the increase of the angular velocities in the wrist joint at the moment of release (Okazaki & Rodacki, 2012), where angular velocities reach their maximum right at the moment of ball release (Walters, Hudson & Bird, 1990) or a few moments after the release (Miller & Bartlett, 1993). However, other researchers (e.g. Miller & Bartlett, 1996) claim that the angular velocities in the wrist at the time of release decrease with a longer shooting range. While interpreting the results of the studies done on this topic, it is important to be aware of the fact that these explorations were done with different samples of players in terms of gender, age, and experience (Okazaki, Rodacki & Satern, 2015). Satern (1993), for example, found out that angular velocities were higher in women than in men, despite the same shooting range. The reason for this is supposedly a higher ball release point of male players, which is due to the fact that men are taller than women (Škof, 2007). The angular velocities also depend on the upper extremity strength of basketball players, which influences both the technique and accuracy of the throw (Justin, Strojnik, & Šarabon, 2006; Kauranen, Siira, & Vanharanta, 1998; Tang & Shung, 2005; Woolstenhulme, Bailey, & Allsen, 2004).

When load is smaller or in an open kinetic chain (e.g. throwing at the hoop), the movement is done sequentially. This means that body segments move in a certain order along time (Hudson, 1986). The forces that act on a certain joint are, in ballistic multisegment movements, transferred to the next joint and so on until the forces are finally transmitted to the projectile (in our case the ball). This efficient cooperation of adjacent joints in the kinematic chain is referred to as the proximal-distal principle. It marks a movement strategy of multi-joint movements where body segments are integrated in a certain sequence. The proximal body parts start the movement and later the sequence moves from the proximal to the distal body parts. This principle is also efficiency advantageous due to the fact that most of muscle mass is closer to the torso (proximal) so that the distal segments are less burdened with the mass that impedes speed of the movement (Cleland, 1866). This also ensures an easier motor control over complex movements (Hogan, 1985), a part of which is also a basketball throw.

The aim of the research was to investigate the effect of shooting range on joint angular velocities in the lower and upper extremities and to describe joint angular velocities during the whole cycle of a jump shot performance, including the difference between the left and right leg. Because we assumed that the proximal-distal principle was an important aspect of a successful (accurate) throw and was at the same time closely connected to the correct technique of the basketball shot, we wished to test if there was an intersegmental correspondence of angular velocities in basketball jump shots performed by young basketball players. Since in the available literature we have not yet found a research on angular velocities of basketball shots of young players and since we presumed that their angular velocities differed from the angular velocities of older (top-level) basketball players, we included players from the age category of cadets (U16) in our research.

Methods

Participants

Our sample consisted of 14 top-level young basketball players from Slovenia (average age 15.43±0.51 years), occupying the playing position of guards. The average height of the participants was 187.14±5.57 cm and their average body mass was 74.76±5.41 kg. Their mean basketball experience was 7.2±2.5 years. The chosen players were on the either a short or wider list of players for the Slovenian national cadet team and played in the highest men basketball division in Slovenia. We have chosen the playing position of guards because their kinematic parameters of shooting at the hoop would, presumably, change evenly when we increase the distance (Miller & Bartlett, 1996; Walters, et al., 1990) and because they usually make their throws from a longer distance (Trninić, 1996). Previous research also shows a high correlation between the position and the anthropometric characteristics, which considerably differentiate between different types of basketball players (Erčulj, 1998; Dežman, Trninć, & Dizdar, 2001; Carter, Ackland, Kerr, & Stapff, 2005; Erčulj & Bračič, 2010). So, only one player type should warrant a greater homogeneity of the sample in terms of players' physical characteristics. All the participants were right-handed. They participated voluntarily in the measurements after the signed informed consent of their parents had been obtained as well as the approval of the local ethics committee. The participants had no injury that could have affected the results or performance of throws.

Measures

In order to analyze technique of the throw, that is kinematic parameters of the basketball jump shot, we used the MVN inertial suit MVN Biomech Pro-Inertial motion capture (Xsense, Enschede, The Netherlands). Previous studies have showed that this kind of equipment is appropriate for the analysis of sports movements when it comes to short physical actions, such as the jump shot (Krüger & Edelmann-Nusser, 2010; Supej, 2010; 2011). The moment when the ball is released from the hand cannot be determined by the MVN program, so we also used a Casio Exilim – F1 camera that takes up to 300 photos per second. It was placed perpendicularly to the direction of the throw, on the side of the shooting hand. To synchronize both systems, each participant hit the ground with his right foot before performing the assignment.

Since the MVN Studio (Xsense, Enschede, The Netherlands) allows only a display of the data measured by the MVN inertial suit, we entered the measured data into Excel (Microsoft, Redmond, USA) using our own program Moven 2 Excell (Supej, 2012). We have divided the throw into three phases – preparation phase, jump phase and follow-through phase, which is consistent with previous research (Lamb, Bartlett, & Robins, 2010; Miller & Bartlett, 1996) and take into account the definition of the jump shot (Official Basketball Rules, 2012). The participants performed all the throws from all ranges in the same manner. The preparation phase lasted from the moment of the downward movement, or from the point when the hind leg was connected with the standing leg (if the participant had moved his leg before the throw) to the moment when both feet left the ground (take-off). The jump phase lasted from the take-off to the release, that is, the moment when the ball left the hand. The follow-through phase lasted from the release to the moment when both feet touched the ground (landing).

Procedures

A standard procedure before the measurement required a correctly installed equipment, the entry of anthropometric measurements of each player, and calibration. After the initial ten-minute warm-up, the participants were free to throw the ball from three different distances. The distances were marked on the longitudinal center line of the court and were 1.5 m apart. Each player first took the throw from the first distance (3.75 m), then from the second distance (5.25 m), and, finally, from the third one (6.75 m). The distances were longer than in the previous studies (Diehl, Tant, Emmons, & Osborn, 1993; Miller & Bartlett, 1993; 1996; Robins, Davids, Bartlett, & Wheat, 2008; Satern, 1993; Walters, et al., 1990) since the rules had been changed in the meantime and the three-point area was increased (Official Basketball Rules, 2010). The participants were given instructions to perform jump shots that would resemble as closely as possible the shots performed in practice and games. Because we did not wish to affect natural technique of players and, consequently, results of the measurements (Miller & Bartlett, 1996), the participants stood on the marked spot, while one of their legs was allowed to be placed slightly backward. Each participant first performed several warming-up throws from each distance. Each participant hit the ground with his right foot before the assignment execution for the purpose of equipment synchronization. In order to allow the throwers to concentrate only on the throw, the ball was picked up by the other person, who then handed it from beneath the hoop and also gave a sign for the next throw. The task was to score ten field goals from each distance, which was completed to a certain extent. We had them throwing the ball at an interval of ten seconds since we wished to analyze shooting technique, so the players should have not be exhausted. Also to prevent exhaustion, the number of attempts from one distance was limited to the maximum of 25 throws. Further analysis included only the scored throws.

Data analysis

The analysis included 370 field goals; 128 throws taken from the first (the shortest) distance, 129 from the second distance, and 113 from the third distance. The joint angular velocity was calculated by the time differentiation of the joint angles as retrieved from the MVN system, measured in degrees (°). We marked the maxima of the angular velocities and put them into a time frame. To the observer of the kinetic chain of movements, these maxima deliver information about the occurrence of the proximal-distal principle. While observing the angular movement of joints, we have only taken into account one direction – in most of the joints we were focused on the extension/flexion movement, whereas in the shoulder joint we were interested in the anteflexion/retroflexion movement and in the upper ankle joint we were monitoring the plantar flexion/dorsiflexion movement. In general, flexion presents positive values and extension the negative ones. For the upper ankle and shoulder joint positive values represented dorsiflexion and retroflexion, while negative values represented the plantar flexion and anteflexion. None of the parameters needed any further filtering, which can be explained by the fact that the MVN system natively measures three dimensional angular velocities in each sensor.

In order to compare the throws, the information was interpolated in a way that all throws matched the number of points from the beginning to the end of each phase. The interpolated phases of each throw were then combined into an entire throw. The preparation phase represented 60% of the time of a throw, the jump phase 15%, and the follow-through phase 25%. The interpolation was done by the Cubic Spline function in Excel with the plug-in SRS1 Cubic Spline for Excel. For a better overview of the timeline, we selected the time 0, which marks the moment of ball release.

The dependent variables were: angular velocities of the shooting hand at the moment of the release, angular velocities of the lower extremities at the moment of a take-off, maximum angular velocities and time of the maximum angular velocities of the shoulder, elbow, wrist, hip, knee, upper ankle, and metatarsal-phalangeal joint. The obtained results were processed using the software package SPSS (version 18) (IBM, Armonk, New York). Statistically significant differences between the variables for the three shooting ranges were checked by ANOVA for dependent samples. Wherever the differences were statistically significant, we used the Bonferroni method of multiple comparisons (a part of *post-hoc* tests), for a more detailed analysis of the obtained differences. This method clearly showed between which distances the statistically significant changes occurred. Statistical significance was tested using a two-tailed *t*-test was run with an alpha error of 5%. The average values were calculated from the average of the throws of each player. The comparison between the left and right foot was tested using a two-tailed *t*-test for independent samples. Line charts were used to graphically present the throw in its entirety.

Results

The maximum angular velocities of the elbow and shoulder joint increased when the distance of the throw was increased, as did the angular velocities of the release (Table 1). This also applied to the wrist joint, with the exception that the values of the release were higher with the second (middle) distance than with the third (longest) one. Based on the beginning of the throw the maximum angular velocity appeared much closer to the release when the distance was increased.

There were differences between the left and right foot in terms of the angular velocity of the lower extremities during the jump shot performance (Table 2). With the knee and upper ankle joint the velocities were higher in the left foot, while the angular velocities of the metatarsal-phalangeal joint were higher in the right foot. The differences between the variables for the three shooting ranges were seen in the knee and left hip joint where angular velocities of the take-off were higher for the first distance. The maximum angular velocities were generally similar for the first and second distance, but were higher for the third distance. The maximum velocities appeared closer to the release when the distance was increased and they differed according to the shooting range. There were no changes between the left and right foot in terms of the maximum values and the time when – based on the release – these values occurred.

Table 1. Angular velocities of the shooting (right) hand (in the direction extension/flexion) at the moment of ball release, the moment of maximum angular velocity, and the time of the maximum angular velocity

	D	AVR (°/s)	MAV (°/s)	TMAV (s)
Shoulder joint	3.75	233.3±88.72	**443.2±78.92**[a]	-.11±0.13
	5.25	288.6±128.61	**566.6±118.03**[b]	-.03±0.02
	6.75	305.1±203.44	**718.6±174.26**[c]	-.02±0.02
Elbow joint	3.75	541.4±235.21	**923.4±86.45**[a]	**-.04±0.02**[a]
	5.25	706.1±309.42	**1,063.4±123.9**[b]	-.03±0.02
	6.75	715.7±372.34	**1,212.4±158.82**[c]	-.03±0.02[c]
Wrist joint	3.75	1,157.1±349.02	1,528.3±383.25	**.00±0.02**
	5.25	1,217.4±328.11	1,690.1±586.66	.00±0.02
	6.75	1,204.6±371.87	1,731.4±658.59	.01±0.02

Legend: D – distance (m); [a] – statistically significant difference between the first and second distance; [b] – statistically significant difference between the second and third distance; [c] – statistically significant difference between the first and third distance; AVR – angular velocity of the release; MAV – maximum angular velocity; TMAV – time of the maximum angular velocity.

Table 2. Angular velocities of the lower extremities at the moment of the take-off, the moment of maximum angular velocity, and the time of the maximum angular velocity

		Right foot			Left foot		
	D	AVJ (°/s)	MAV (°/s)	TMAV (s)	AVJ (°/s)	MAV (°/s)	TMAV (s)
Hip joint	3.75	109.3±75.14	290±75.96	**-.25±0.05**[a]	**123.1±70.89**[a]	290.4±74.89	**-.25±0.05**[a]
	5.25	94.1±46.74	**297.6±66.15**[b]	**-.21±0.05**[b]	90.9±53.64	**292.4±61.38**[b]	**-.2±0.04**[b]
	6.75	96.4±50.63	**335.7±60.84**[c]	**-.18±0.03**[c]	88.4±59.46	**332.9±62.38**[c]	**-.17±0.03**[c]
Knee joint	3.75	**225.3±102.45**[a1]	486.1±96.1	**-.26±0.08**[a]	**310±78.89**[a1]	472.4±96.12	**-.24±0.05**[a]
	5.25	**161.4±84.59**[1]	478.5±96.01	-.21±0.06	**241.7±65.66**[1]	462.8±100.07	**-.19±0.04**[b]
	6.75	**137.6±88.29**[c]	500.8±82.25	**-.18±0.05**[c]	**194.5±95.83**[c]	482.2±78.52	**-.16±0.03**[c]
UAJ	3.75	**213.8±77.58**[1]	636.1±138.95	**-.23±0.05**[a]	**364.8±131.28**[1]	654.7±131.67	**-.22±0.06**[a]
	5.25	**178.8±104.31**[1]	**638.5±157.56**[b]	**-.18±0.05**[b]	**342.4±114.43**[1]	662.8±148.7	**-.16±0.05**[b]
	6.75	**149.9±94.79**[1]	**696.2±128.02**[c]	**-.15±0.04**[c]	**335.7±119.6**[1]	694.6±114.13	**-.13±0.04**[c]
MP joint	3.75	**572.4±325.47**[1]	870.5±304.58	-.17±0.06	**173.5±105.69**[1]	991.1±246.87	**-.16±0.06**[a]
	5.25	**611.7±358.97**[1]	855±331.66	**-.13±0.05**[b]	**136.4±84.57**[1]	1,006.4±273.33	**-.1±0.05**[b]
	6.75	**452.5±316.28**[1]	856.6±332.33	**-.08±0.05**[c]	**178.9±148.24**[1]	970.5±300.82	**-.07±0.05**[c]

Legend: D – distance (m); [a] – statistically significant difference between the first and second distance; [b] – statistically significant difference between the second and third distance; [c] – statistically significant difference between the first and third distance; [1] – statistically significant differences between the left and right foot; MP joint – metatarsal-phalangeal joint; UAJ – upper ankle joint; AVJ – angular velocity of the take-off; MAV – maximum angular velocity; TMAV – time of the maximum angular velocity.

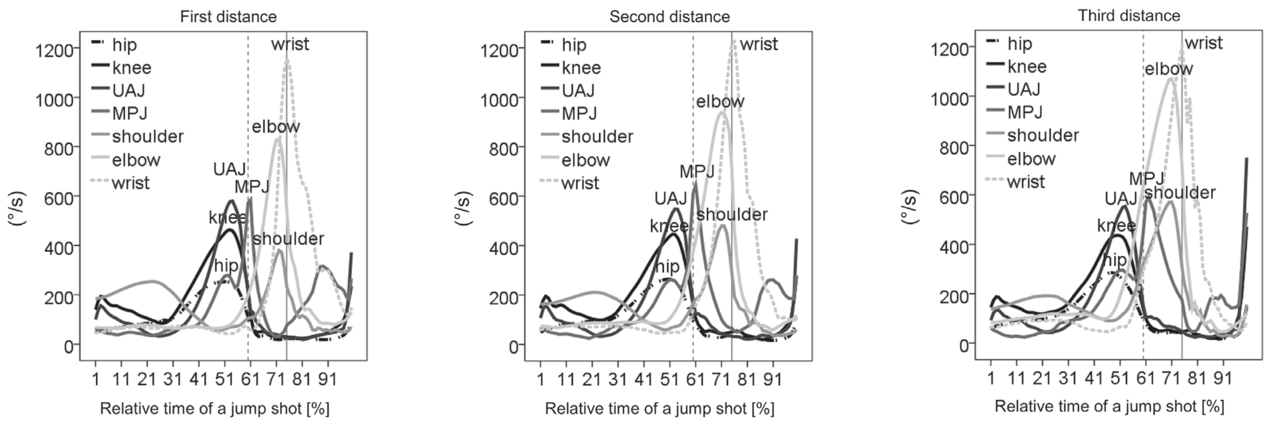

Figure 1. The display of overall average joint angular velocities (°/s). The dotted line on the x-axis represents the moment of the take-off, while the continuous line marks the moment of ball release.

Figure 1 clearly shows the moment when, during the shot performance, the maximum angular velocities appeared in the joints of the right leg (hip joint, knee joint, upper ankle joint – UAJ, and metatarsal-phalangeal joint – MPJ) and the shooting arm (shoulder joint, elbow joint, and wrist joint). The maximum angular velocities of the wrist joint showed no statistical differences between shooting ranges, which was not the case with angular velocities of the shoulder and elbow joints (Table 1). The maximum angular velocities in arm joints during the shot performance from the closest distance started at the shoulder joint, then moved to the elbow and wrist joint, while during the throw from the second distance the maximum angular velocities of the shoulder and elbow joint occurred almost simultaneously. With the throw from the longest distance the maximum angular velocity of the elbow joint occurred before the maximum angular velocity of the shoulder joint. Time of the maximum angular velocities in joints of the lower limbs did not change with the increase in distance. The occurrence sequence was as follows: hip joint, knee joint, upper ankle joint, and metatarsal-phalangeal joint. The exception was the right hip and knee joint where the maximum values appeared almost simultaneously.

The proportions of the maximum joint angular velocities in the shooting arm changed when the distance of the throw was increased. The ratio shoulder – elbow – wrist joint corresponded to the ratio of 1 – 2.14 – 3.52 with the first distance, 1 – 1.94 – 3.06 with the second distance, and 1 – 1.75 – 2.53 with the third distance. In this way the values of the angular velocities in the distal joints (elbow and wrist joints) decreased according to the proximal joint (shoulder joint). The statistical differences between proportions of the maximum joint angular velocities for the three shooting ranges were found when it came to the ratio elbow – shoulder ($p<.017$) as well as with the ratio wrist – shoulder ($p<.024$). The proportions of the maximum angular velocities in the joints of the right leg decreased as well.

Discussion and conclusions

The results have shown that the maximum angular velocities in the shoulder and elbow joints of young basketball players increase when the distance increases, whereas this does not apply to the wrist joint. The angular velocity of the take-off, no matter the distance, varies in the left and right foot, which is a consequence of an asymmetrical lower limbs' movement. The proximal-distal principle of the maximum angular velocities in shooting arm depends on the shooting range since the principle applied only to the first distance. The proportions of the maximum angular velocities in the joints of the shooting arm change with the distance. If we increase the distance, the angular velocities of the proximal joint (shoulder joint) increases more than the angular velocities in the distal joints.

The angular velocities in the shooting arm at the moment of ball release generally increase, although the differences between the three shooting ranges were not statistically significant (Table 1). Despite the fact that the distance was increased evenly (progressing by 1.5 m between each distance), this did not apply to the joint angular velocities. The velocities increase considerably from the first distance to the second one, while they are fairly similar for the third and second distance. Despite the shorter shooting ranges of older basketball players, Miller and Bartlett (1996) report higher angular velocities in the shoulder and elbow joint at the moment of ball release. For the distances of 2.74 m, 4.57 m, and 6.4 m from the hoop these velocities add up to 241 °/s, 338 °/s, and 430 °/s for the shoulder joint and 647 °/s, 791 °/s, and 905 °/s for the elbow, respectively. As we can see, the velocities increase more evenly with the increase in distance. The same results were presented by Okazaki and Rodacki (2012), who also analyzed throws of adult basketball players. Their results show that the angular velocities in the shoulder joint amount to 223.1 °/s, 272.7 °/s and 346.5 °/s in throws from the distances of 2.8 m, 4.6 m and 6.4 m, respectively. The reason for these discrepancies may lie in the age of the participants since the average age was 24.8 (±4.2) years in the first research and 25 (±2) years in the second research. It is different with the maximum angular velocity; the angular velocities in the shoulder and elbow joint increase with the distance increases. These angular velocities are also higher when compared to the angular velocities of the aforementioned studies. Just as an example, the angular velocities in the elbow joint amount to 665.8 °/s in the shot performance from the distance of 2.8 m, 743.3 °/s from the distance of 4.6 m, and 851.6 °/s from the distance of 6.4 m (Okazaki & Rodacki, 2012). Given the fact that the motor abilities are fully developed at adult age (Škof, 2007), it is clear that younger players use different strategies of shooting at the hoop. It is possible that, when it comes to ball release, younger basketball players are not proficient in motor control and, simultaneously, they do not develop kind of speed that would enable an accurate throw. That is why they attempt to increase the speed of their limbs by increasing the maximum angular velocities before ball release. In this way, temporal sequences of maximum velocities are demolished. Decreasing proportions between the maximum angular velocities of the shooting arm joints point to the fact that the angular velocity of the proximal parts increases with distance.

It was expected that the angular velocity in the joints of the lower extremities at the moment of take-off would increase with distance (Table 2). We were proven otherwise – the angular velocities decreased at the take-off, with the exception of the metatarsal joint. Furthermore, differences appeared between the left and right foot. The reason for this can largely be contributed to the fact that the feet do not leave the ground at the same time. In most cases it was the right foot that left the ground first and only then the left followed (this was also the moment of the take-off since our criterion was defined as the moment when both feet left the ground). This is also proven by the time point in which the angular velocities reached their maximum values – the right leg reached the maximum values first, followed by the left leg. The mentioned applies to all the joints and all the distances. This is also why, at the moment of the take-off, the angular velocities in the knee joint and the upper ankle joint are higher in the left leg since the angular velocities of the right leg have already decreased after the take-off. The opposite applies to the metatarsal joint because the angular velocities of the left foot keep increasing and are therefore lower in comparison with the right metatarsal joint. The reason lies in the fact that, generally, players throw at the basket using one hand – in our case the right one.

When observing the way in which the segments are included into kinematic analysis, it is best we take a look at the moments in which the maxima of the angular velocities of the segments, incorporated into the kinematic chain, appear. This enables us to determine whether there is a simultaneous or sequential integration. We discovered that increasing distances decreased the angular velocities of take-off (Table 2), so it is most likely that control over the maximum angular velocities enables intersegmental agreement, which leads to optimal velocities of the segments during the jump shot performance. When we take a look at the shooting arm throwing from the first distance, we can say that, from the aspect of intersegmental agreement, the maxima of angular velocities appear as follows: shoulder – elbow – wrist joint (Figure 1). This kind of cooperation between the adjacent joints in the kinematic chain (proximal-distal principle) transfers energy through the kinetic chain (Stodden, Fleisig, McLean, & Andrews, 2005). We would expect that this sort of sequence of the maxima angular velocities would also appear in the jump shots from longer distances, but it is not so. From the second distance the maxima angular velocities of the shoulder and elbow joint appeared almost simultaneously, whereas from the third distance the maximum angular velocity in the elbow joint appeared even before the maximum of the shoulder joint. The same pattern has been identified for the maximum resultant velocity of the shooting arm, even though the throwers were male adults and the distance for the three-point throw was shorter (6.25 m) (Elliott, 1991). Opposite happens in the joints of the lower extremities since no difference between the variables was obtained for the three shooting ranges. The proximal-distal principle is, therefore, noticeable for all the distances.

The results are somewhat unexpected if following the theory that the proximal-distal principle ensures maximum output values (Urbin, Stodden, Fischman, & Weimar, 2011). From the first distance, where the aspect of strength is not questionable and where the jump is the highest, the participants adhered to the proximal-distal principle with the shooting arm. It seems that from short distances, from where we could successfully make a throw even without moving the feet, we comply with the proximal-distal principle of the shooting arm to achieve accuracy of a throw. However, with the three-point throws, where strength of the shooting arm is too low, we need to ensure enough force by the jump itself. Thus, jumping from the third distance is not intended to achieving a greater release height since ball release appears in the phase of ascension. The same temporal sequence in maximum angular velocities of the legs helps achieve a successful (accurate) throw. The logical conclusion would therefore be that, while aiming for the target, the proximal-distal principle does not play a major role only for ensuring maximum force, but also plays an important part when it comes to ensuring accuracy of the young basketball players' throws.

Some authors are of the opinion that the adherence to the proximal-distal principle depends on players' experiences (Chiang & Liu, 2006; Miller & Jackson, 1995). The aforementioned principle supposedly appears in experienced quality players, while the maxima of joint angular velocities in the hip and knee are synchronized in beginners. However, the mentioned studies are not unanimous when it comes to the application of the proximal-distal principle to the shooting arm. The first research shows that the experienced players use the proximal-distal principle, whereas the authors of the second research reject the use of this principle and advocate for a larger flexibility of basketball players. These inequalities may be attributed to an heterogeneous sample or to the use of different distances. In our research the temporal sequences of maximum velocities of the lower extremities are the same for all the three distances, while the proximal-distal principle of the upper extremities is present only for the first distance. The transition between the joints of the upper and lower extremities (more precisely, of the shoulder joint and the right upper ankle joint) is the shortest with the first distance (0.12 s) and the longest with the second distance (0.15 s). With the third distance it is very similar to the first one (0.13 s). Similar features of time span can also be found between the metatarsal-phalangeal joint of the right leg and the shoulder joint (0.06 s; 0.1 s; 0.06 s), with the differences between the variables of the three shooting ranges being somewhat higher. Based on the findings that the time of the transition increases with the decreases in players' experiences (Miller & Jackson, 1995), we can presume that the throws from the second distance are therefore least beneficent.

With the third distance the maximum angular velocities of the hip joint and the right upper ankle joint increased, while the maximum velocities in the shoulder and elbow joint increased with all the three distances. The proximal-distal principle is observed in the shooting arm in throws from the first distance, whereas temporal sequences of maximum velocities of the lower extremities are preserved from all the three distances. Because of this we cannot confirm the findings of Chiang and Liu (2006) claiming that with the increased distance the movement of the lower extremities change, while the movement is preserved in the upper extremities, which enables a good motor control of throws. According to the results of the maximum angular velocity and the time point in which it has been achieved, this was not the case in our research.

We were aware that the used measuring technology could somewhat influence throw performance. Yet we decided to use it because it enabled the acquisition and processing of a larger quantity of information in a relatively short time. This can also be seen in the number of analyzed throws, which is essentially larger than in similar studies. Furthermore, the participants did not find sensors an obtrusive factor and at the same time they were given enough time and warming-up throws. Restrictions of our research can be seen in the fact that the measuring technology, used to collect information, does not measure kinematic parameters of the fingers, which are the last segments directly affecting the ball trajectory. Consequently, they represent an important part in the kinematic chain of shooting at the basketball hoop.

Our research, based on the sample of young but already experienced basketball players (U16) who take the position of guards, give an insight into what is happening with the joint angular velocities and how they change when we increase shooting range. The results of this research, compared with the previous research, show that young basketball players employ different strategies of shooting at the hoop than adult players. The maximum joint angular velocities of the shooting arm (the shoulder and elbow joint) increase with the increase in the shooting range. The proximal-distal principle of the shooting arm movements is respected only in throws from the first distance, but temporal sequences of maximum velocities of the lower extremities are preserved in throws from all three distances. These facts indicate that the lower extremities play an important part in the accuracy of the three-point throw, which suggests a need for certain changes in the usual approach to teaching the techniques of shooting at the hoop from a greater distance. At the same time, it opens certain new questions that can only be answered with further research.

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