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MOVEMENT OF THE BODY'S CENTRE OF MASS DURING A JUMP SHOT RELATED TO THE DISTANCE FROM THE BASKET OF YOUNG PLAYERS

GIBANJE CENTRALNEGA TEŽIŠČA TELESA PRI METU IZ SKOKA GLEDE NA ODDALJENOST OD KOŠA

ABSTRACT

The aim of the study was to describe, in the conditions of rest, the change in position and/or movement of the body's centre of mass (CoM) of young male basketball players (cadets) during a jump shot from three different distances. The measurements of kinematic parameters during the shot were made using an inertial suit. The results show that the ball release occurs at different levels of the flight curve. On the shortest distances it occur 0.05s after reached maximum height in the vertical direction, on the middle distance on the peak and on largest distance 0.03 s before reaching the maximum height. The time from the beginning of the shot and take-off to the ball release shortens with an increasing distance from the basket. The time from the ball release to the landing increases with an increasing distance. In the direction towards the basket the shift increases with a longer distance until the take-off, whereas in the case of the longest distance it decreases or stops after the take-off. In the case of the longest distance, the movement of the CoM in the lateral from basket results in the largest shifts and it is statistically different from shorter distances at the beginning of the throw and at take-off ($p < 0.01$). From the beginning of the throw to ball release the lateral shift is 11 cm. It can be concluded based on the results that the movement of the CoM of young male basketball players and consequently the technique of shooting at the basket changes with distance. This is a very important finding for coaches who must be acquainted with the adjusted technique and consider this fact in the training of young basketball players.

Key words: basketball, young male, kinematics, trajectory

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IZVLEČEK

Cilj raziskave je bilo v spočitih okoliščinah opisati, kaj se dogaja s položajem oz. gibanjem točke centralnega težišča telesa (CTT) pri metu iz skoka iz treh različnih razdalj pri mladih košarkarjih (kadetih). Meritve kinematičnih parametrov pri metu na koš smo opravili z inercialno obleko. Rezultati so pokazali, da se izmet zgodi na različni stopnji krivulje leta. Pri najkrajši razdalji pride do izmeta 0.05 s po dosegu maksimalne višine, pri srednji razdalji v trenutku maksimalne višine, pri najdaljši razdalji pa 0.03 s pred dosego maksimalne višine. Čas od začetka meta in odriva do izmeta se z večanjem razdalje skrajšuje, čas od izmeta do doskoka pa se z razdaljo podaljšuje. V smeri proti košu (smer X) se premik z večanjem razdalje do odriva povečuje. Gibanje CTT v smeri Y pri največji razdalji omogoča največje premike in se v začetku meta in trenutku odriva statstično značilno razlikuje od najkrajše in srednje razdalje ($p < 0.01$). Pri največji razdalji ta odmik od začetka meta pa do izmeta znaša 11 cm. Na osnovi rezultatov lahko zaključimo, da se pri mladih košarkarjih gibanje CTT in posledično tehnika meta na koš z razdaljo spreminja. To spoznanje je zelo pomembno tudi za trenerje, ki morajo biti seznanjeni s prilagojeno tehniko in hkrati to dejstvo upoštevati tudi pri treniranju mladih košarkarjev.

Ključne besede: košarka, mladi, kinematika, trajektorija

INTRODUCTION

Shots from longer distances require greater shooting accuracy (Elliot, 1992) as the horizontal imaginary angle at the ring decreases with an increasing distance from the basket. Greater accuracy is also required because of the ball release conditions that become worse over an increasing distance. Two of the most important parameters are the release angle and release height. Both decrease with an increasing distance (Satern, 1993; Miller and Bartlett, 1996; Okazaki and Rodacki, 2012), and thus the possibility of a successful shot also decreases (Podmenik, Leskošek, & Erčulj, 2012). To achieve a higher flight curve (greater release angle and angle of incidence), the arms and the shoulder girdle require more developed strength which is problematic in long distance shots, especially among basketball players with less developed muscle strength (Škof, 2007). Players often compensate for this shortcoming by directing the take-off impulse during a shot at the basket more forwards and less upwards. Such modification of the shooting technique is not desired by coaches as it is mainly considered to negatively affect the precision (efficiency) of the shot, increase the possibility of an offensive player making a personal foul and require more space for shooting (Podmenik, Leskošek, & Erčulj, 2012; Filippi, 2011).

The technique and accuracy of a shot at the basket are related to the strength of a basketball player's upper extremities (Kauranen, Siira & Vanharanta, 1998; Carroll, Carson & Riek, 2001; Woolstenhulme, Bailey & Allsen, 2004; Justin, Strojnik and Šarabon, 2006; Tang and Shung, 2005). Younger players have not yet fully developed their muscle strength which is why they are weaker (American Sport Education Program, 2001). We assume this to have a specific effect, especially on the shooting technique from a longer distance where one needs more muscle strength. Apart from the already mentioned modification of the take-off angle that is directed more horizontally (towards the basket), the ball release occurs in the earlier phase of the shot (jump) or nearly simultaneously with the take off. Such modification of the shooting technique is particularly frequent with young basketball players when taking a long shot. The above is confirmed by the findings of some basketball experts (Filippi, 2011) who observed that differences in the shooting technique of young basketball players depend on the distance from the basket. These players apply a specified technique when shooting at the basket from a closer distance, whereas in the case of a long distance their technique changes and/or adapts to new conditions. It is a transition phase until they reach a higher level of muscle strength. Unfortunately, such observations and findings of the experts are still not supported by appropriate research.

Knowing the changes in technique became even more important and interesting when the basketball rules were amended in 2010 (International Basketball Federation, 2010). One of the amendments also involved moving the three-point line further away from the basket. Since then the three-point shot must be made from a distance of 6.75 m or more (previously 6.25 m). Earlier the players only rarely decided to shoot from this distance, but after the rules were amended such shots have become very frequent. This also applies to younger age categories where the problem with adjusting the technique of long shots is, in our opinion, even more prominent because of the less developed muscle strength.

The studies of the kinematic parameters of shots at the basket were primarily conducted in two planes, using shortest distances from the basket and exclusively with adult basketball players. We could not find any study that presented the entire movement of the body during a shot at the basket in three planes. Therefore, in our study we decided to focus on observing the body's centre of mass (CoM). If this is true the changes will undoubtedly be reflected in the trajectory of the movement of the CoM. In the past, researchers (Elliot, 1992; Satern, 1993; Okazaki and Rodacki, 2012) captured and analysed data from video recordings where the camera was positioned laterally relative to the study subjects. From this position it was determined what occurs during a shot at the basket in the sagittal plane, especially at the time of releasing the ball. This single camera technique was unable to determine the movements occurring in the frontal and transverse planes.

The aim of this study was to describe the position and/or movement of the body's centre of mass (CoM) during a shot from three different distances made by young male basketball players (cadets). As the shooting technique is connected with a player's strength (Justin et al., 2006; Kauranen et al., 1998; Sklerynk & Bedingfield, 1985; Tang & Shung, 2005; Woolstenhulme et al., 2004), we concluded that these movement patterns between the distances changed and that this was particularly true for younger basketball players, who have so far not yet received research attention. This was also the reason for including in the sample of subjects high-quality 15- and 16-year-old players whose shooting technique is relatively well developed but whose muscle system is not yet fully developed which is why they are physically weaker than adult players. We assumed that the time from the beginning of the shot (take-off) to the ball release will be shorter with an increasing distance from the basket, and the time from the ball release to the landing will be longer. With an increasing distance from the basket, the subjects will jump towards the basket when shooting. We also assume that the absolute maximal and minimal height of the CoM, along with the height of the point of ball release, will decrease with a shorter distance from the basket. There will be no differences between the distances in terms of lateral shifts (Y – direction).

MATERIAL AND METHODS

Subjects

The sample of subjects included 14 elite Slovenian young male basketball players – guards, aged 15.4 ± 0.5 years who are members of the Cadet National Team of Slovenia, either in the core team or in the squad generally. The shooting arm of all subjects was the right arm. The subjects parents provided their written consent and participated voluntarily in the measurements that had been approved by the Ethical Committee according to the Decleration of Helsinki II. They had no injuries that could affect their jump shot. Their average height was 187.1±5.6 cm and average weight 74.8±5.4 kg.

Measurements

After an initial ten minutes of warming up, the subjects shot freely at the basket from three positions (distances) along the longitudinal centre line of the court, with the distance between them measuring 1.5 m. Each study subject first shot the ball from the 1^{st} distance (3.75 m), followed by the 2^{nd} (5.25 m) and the 3^{rd} (6.75 m). The distance of 6.75 m represents the limit of the area from which a successful shot is awarded three points. Thus, according to the basketball criteria, the analysis included shots from short, medium and long distances. The study subjects were instructed to perform a jump shot similar to the manner in which they perform shots during training and matches. As we did not want to influence the natural technique of a player and thus the results of the measurements (Miller and Bartlett, 1996), the subjects could do a small back step of one foot. If a player did choose this option, the data were analysed after the step from the rear foot . They were instructed to shoot directly at the basket, without the basketball bouncing off the backboard. At every distance, the subject first had a few test shots. All measurements were recorded with two measurement systems that had to be synchronised. For the purpose of the synchronisation, the subject hit the floor with his right foot before starting to perform the task. Using this movement action it was possible to determine the starting point that is clearly seen in both measurement systems. To enable the subject to focus only on the shot, the ball was picked up by another person who passed it back to the subject from under the basket and also gave a sign for the shot to begin. The goal of the study subjects was to score ten shots from every distance. They shot at the basket in 10-second intervals, as our study aimed to analyse the shooting technique in the conditions of rest. In line with this goal, i.e. to prevent fatigue, which could influence the movement of CoM, the maximum number of shots performed from a single distance was 25.

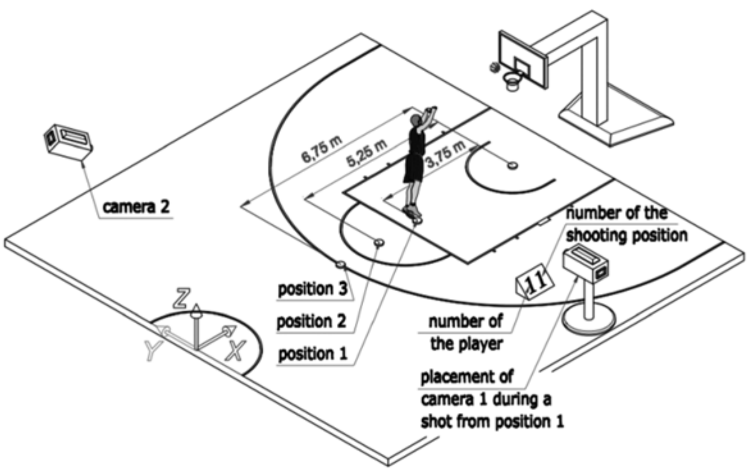


Figure 1. Presentation of the measurement protocol

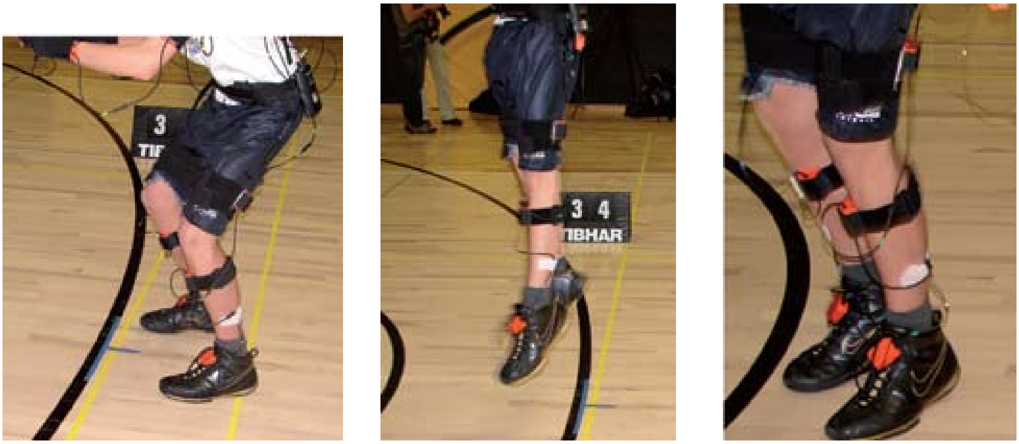
The shooting technique and/or kinematic parameters during a jump shot was measured using the inertial suit "MVN – Inertial motion capture" (Xsense, Enschede, Netherlands) (Figure 2). It enables real-time measurement with 120 images per second in a 3D space. MVN system gives an estimate of the CoM based on the segment positions together with a body mass distribution model (Roetenberg et al., 2013). The measurements were also recorded with a Casio Exilim – F1 (300 Hz) camera that was placed perpendicularly to the direction of the throw on the shooting arm side. At the same time, we used the AXIS P5534 Network Camera that was fixed to the ceiling of the hall and recorded the entire measurement procedure. It provided us with information about the success of every throw.

Figure 2. The kinematic parameters during a jump shot were measured using the inertial suit "MVN"

Variables

The analysis included 370 successful shots. From the first position 128 shots were scored, from the second 129 and from the third 113. During the jump shot we observed the movement of the CoM in all three directions (towards the basket - X, lateral from basket - Y and vertical from basket - Z). For further analysis of the recorded raw data we use custom made software Moven 2 Excell (Supej, 2012).

According to the previous research (Miller and Bartlett, 1996; Lamb et al., 2010) the shot was divided into three phases. The first phase lasts from the moment the movement turns downward and/or the leg in the back step again joins the standing leg (in cases where the subject moved his leg before the shot) until the moment both feet take off from the ground (take-off). The second phase lasts from the jump take-off to the ball release, i.e. the moment the ball leaves the hand. The third phase lasts from the ball release to the moment both feet touch the ground (landing).



a) *b)* *c)*

Figure 3. Positions of a subject's feets at differnent phases of the shot. a) just before take-off; b) at the ball release; c) after landing

In MVN Studio, the co-ordinate system is defined as the right-handed Cartesian co-ordinate system where the X axis points to the northern magnetic field, the Y axis to the west and the Z axis perpendicularly to the former two. To facilitate the understanding of the results, it was rotated so that the X axis pointed in the direction of the side-line (towards the basket), the Y axis in the direction of the baseline (lateral from basket) and the Z axis perpendicularly to the plane determined by the X and Y axes (vertical from basket) (Figure 1). To calculate the angle of the rotation, every subject walked 20 metres along the side-line of the basketball court towards the basket to which they shot during the shooting measurements.

The starting point of the co-ordinate system is the left foot at the beginning of the first phase. We thus obtained accurate data on the shifts as the placement of the left foot before the ball release was precisely defined. Even though the sample was homogeneous in terms of body characteristics, as it only included guards, the data on the vertical from basket were normalised as a percentage of body height. To facilitate the time analysis we determined the 0 time at the moment of the ball release. It was acquired using an additional high-frequency camera Casio Exilim EX-F1 (Casio Computer Co., Tokyo, Japan) as the inertial suit cannot precisely detect the moment of releasing the ball. As noted earlier, the synchronisation of both measurement systems was carried out based on the right foot hitting the floor. The contact of the foot and the floor is clearly visible on the camera recording and detectable by means of the accelerometer on the right leg in the MVN suit. A synchronisation point was obtained for both systems from a video recording that defined the ball release moment used in relation to the kinematic data from the MVN suit.

The time taken for each of the shots was normalized so that each phase comprised a percentage of the shot time. The first phase lasts 60 percent, the second 15 percent and the third 25 percent of the duration of the shot. The interpolation was made using the Cubic Spline function in Excel with the SRS1 Cubic Spline plug-in for Excel.

Statistical analysis

The results were processed with the SPSS software package (version 18) (IBM, Armonk, New York). The observation of the beginning, take-off, ball release and landing was based on the basic statistics (mean and standard deviation). The mean value was used for the graphical observation of the movement of the CoM. The statistical differences (spatial and temporal) between shots across three experimental distances were established using a one – way ANOVA with repeated measures. The Bonferroni post hoc test was applied to determine where differences occurred. The significance level was set at $p < 0.05$.

RESULTS

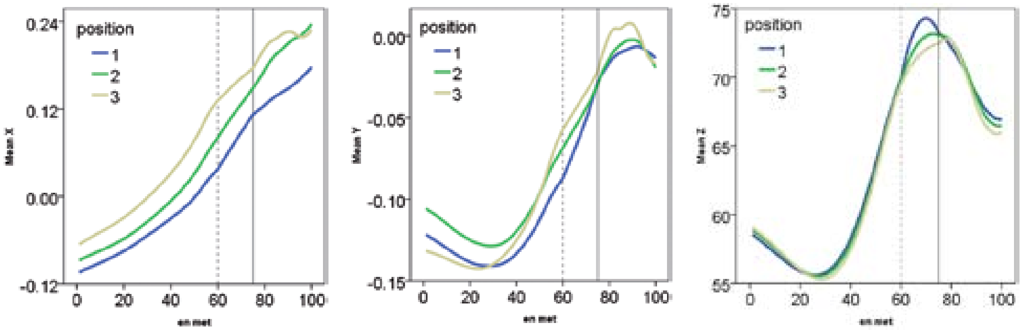
The movement of the CoM in the direction towards the basket increases with the distance (Table 1). The biggest shift is in the 3rd distance until landing where the highest value is achieved by shots from the 2nd distance. The total shift of the CoM towards the basket in the shots from different distances ranges from 28 to 32 cm. In the lateral direction, the shift to the right in the first phase is the largest in case of the 3rd distance. At the time of the take-off, the shift of the CoM during the shot from the 3rd distance is mostly to the left, which is also true for the ball release. At the time of landing the shifts range from 9 to 11 cm to the left (considering the starting point). The height of the CoM (vertical direction) in all phases of the shot (except for the beginning) decreases with an increasing distance from the basket.

Table 1: Position of the body's centre of gravity at the moment of the beginning, take-off, ball release and landing in all three directions (in the X- and Y-directions there are movements of the CoM in relation to the left foot at the start of the first phase; the values in the Z-direction are presented as a percentage of body height) and time (s), when a particular moment occurs

		Towards the basket (m)	**Lateral form basket (m)**	**Vertical from basket (%)**	**Time (s)**
	D	**M⇨SD⇨**	**M⇨SD⇨**	**M⇨SD⇨**	**M±SD⇨**
Beginning	**3.75**	-0.1⇨0.06⇨[a]	-0.12⇨0.06⇨[a]	58.56⇨2.39⇨	-0.62⇨0.15⇨
	5.25	**-0.09⇨0.07⇨[b]**	**-0.11⇨0.06⇨[b]**	58.87⇨2.89⇨	-0.6⇨0.2⇨
	6.75	**-0.07⇨0.07⇨[c]**	-0.13⇨0.06⇨	59.07⇨2.73⇨	-0.55⇨0.19⇨[c]
Take-off	**3.75**	**0.04⇨0.06⇨[a]**	**-0.09⇨0.03⇨[a]**	69.88⇨2.55⇨	**-0.18⇨0.06⇨[a]**
	5.25	**0.08⇨0.06⇨[b]**	-0.07⇨0.04⇨	69.73⇨2.65⇨	**-0.13⇨0.05⇨[b]**
	6.75	**0.13⇨0.07⇨[c]**	**-0.06⇨0.04⇨[c]**	69.49⇨2.54⇨	**-0.09⇨0.04⇨[c]**
Ball release	**3.75**	0.11⇨0.11⇨	-0.03⇨0.05⇨	73.24⇨4.33⇨	0
	5.25	0.15⇨0.11⇨	-0.03⇨0.05⇨	73.06⇨3.83⇨	0
	6.75	0.18⇨0.1⇨	-0.02⇨0.05⇨	72.45⇨3.49⇨	0
Landing	**3.75**	0.18⇨0.12⇨	-0.01⇨0.05⇨	66.93⇨2.56⇨	**0.17⇨0.07⇨[a]**
	5.25	0.24⇨0.13⇨	-0.02⇨0.05⇨	66.48⇨2.76⇨	**0.24⇨0.06⇨[b]**
	6.75	0.23⇨0.14⇨	-0.02⇨0.08⇨	66.01⇨2.66⇨	**0.31⇨0.04⇨[c]**

Legend: D – distance; M – mean; SD – standard deviation;; a – significant difference between the 1st and 2nd distances; b - significant difference between the 2nd and 3rd distances; c - significant difference between the 1st and 3rd distances; bold – $p < 0.01$

As Table 1 shows, the time from the beginning of the shot to the ball release decreases with an increasing distance, although no statistically significant differences are observed between the 1st and 2nd distances and the 2nd ant 3rd distances. The time from the take-off to the ball release also decreases with an increasing distance, yet statistically significant differences occur between the shots from all distances. The time from the ball release to the landing increases with the increasing distance of the shot. The differences between all three distances are also statistically significant.



a) *b)* *c)*

Figure 4. Graph of the average movement of the body's centre of gravity (starting point of the co-ordinate system is the left food at the beginning of the first phase) in the cycle of shot. a) mean towards the basket (m); b) mean lateral from basket (m); c) mean vertical from basket (%). The interrupted line on the X axis represents the time of the take-off and the full line the time of the ball release.

After the ball release, the shift of the CoM towards the basket decreases over the 3rd distance. In the lateral direction, the players (assuming that the release arm is the right arm) all jump, after an initial decline to the right, and land to the left side. At the beginning of the shot at the 3rd distance, the CoM shifts the most to the right in view of the left leg. At the same time, at this distance, the inclination of the curve is the strongest. In the vertical direction there are differences in 1st distance in the phase of flight to the ball release.

Table 2. Presentation of the average maximum (max) and minimum (min) height in the vertical direction as well as their times from different distances (time 0 = ball release)

	Hmax (%)	**Tmax to release(s)**	**Hmin (%)**	**Tmin to release (s)**
D	**M[SD]**	**M[SD]**	**M[SD]**	**M[SD]**
3.75	74.64[4.03]	**-0.05[0.05]**[a]	54.72[3.29]	**-0.43[0.05]**[a]
5.25	73.75[3.73]	**0.00[0.05]**[b]	54.45[3.63]	**-0.39[0.05]**[b]
6.75	73.37[3.46]	**0.03[0.04]**[c]	54.13[4.32]	**-0.34[0.05]**[c]

Legend: D – distance; M – mean; SD – standard deviation;; [a] – significant difference between the 1st and 2nd distances; [b] - significant difference between the 2nd and 3rd distances; [c] - significant difference between the 1st and 3rd distances; bold – $p < 0.01$

The results show that the minimum height of the CoM decreases with an increasing distance from the basket and, in terms of time, it occurs closer to the release of the ball. The maximum achieved height of the CoM decreases with an increasing distance from the basket. In case of the shortest distance, the ball release occurs after the maximum height, in case of the 2nd distance it occurs at the time the maximum height is reached, and at the 3rd distance 0.03 s before the maximum height.

DISCUSSION

As the release conditions with an increasing distance from the basket become less effective (explained in introduction), it was expected that the trajectory of the movement of the CoM would change and adjust to the distance from the basket. While the results did show this, the changes in the movement of the CoM between the distances surprised us. We established that the ball release at the shortest distance occurred after the maximum jump height was achieved and, in the case of the longest distance, before the maximum jump height was achieved. The results show (Figure 4) that the shift in the CoM towards the basket increases with an increasing distance from the basket until the take-off, whereas in the case of the longest distance it decreases or stops after the take-off. With the latter distance, at the starting phase of the shot considering the the left foot (given the fact that the subjects shoot with the right arm) the shift in lateral direction is mostly to the right side, but before the take-off it is mostly to the left side according to the 1st and 2nd distances. The results reveal that the movement of the CoM and, consequently, the shooting technique change and adapt with the distance from the basket.

Previous studies designed to analyse the movement of a shot at the basket were conducted using video analyses, mostly on a two dimensional analysis system (Satern, 1993; Okazaki et al., 2008; Okazaki and Rodacki, 2012). The advantage of this study is that it was conducted using an inertial system which measures movement in a 3D space. The system enables to collect a large amount of data in a relatively short period of time. Because of that we could made measurements on larger sample od subject (compared to similar researches in the past). At the same time, the inertial suit in motor actions of short duration – which is what a jump shot is – proved to be very accurate (Krüger and Edelmann-Nusser, 2010; Supej, 2010; Supej, 2011).

A sample of guards was chosen because, with an increasing distance from the basket, the kinematic parameters in a shot at the basket change more consistently with the guards and because they most often decide to shoot from a longer distance since that corresponds to their playing role (Trninić, 1996). The research also shows a high level of correlation between the playing position and the anthropometric characteristics (Erčulj, 1998; Dežman et al., 2001; Carter et al., 2005; Erčulj and Bračič, 2010). The selection of one type of player thus guarantees greater homogeneity of the sample given the players' body characteristics.

If we compare our study with that of Okazaki and Rodacki (2012), we see bigger shifts of the CoM in the direction towards the basket at the time of the ball release compared to our study. The above two authors report that, during a shot made from 6.4 m, the CoM moves on average by 0.5 m towards the basket, whereas in our study it moved by 0.3 m in the shot from the longest distance (6.75 m). These results are in line with the professional doctrine which asserts that the shift should be a minimum one (Wissel, 1994). An excessive shift of the CoM towards the basket is also not desirable from the point of view of the rules of the game. Namely, this shift increases the possibility that a player will commit a personal foul on offence if there is contact with a defence player. The finding of Rojas et al. (2000) concurs with this, as they found a small shift towards the basket in a shot over a defence player, which is not the case in a shot that is not hindered by a defence player.

The shifts towards the basket increases evenly with an increased shooting distance until the time of take-off. After the take-off the shift is the largest in the 3rd distance but the curve is flatter. Our data do not reveal the reason for such a movement of the CoM. However, the results are in line with the findings of Satern (1993) and the Miller and Bartlett (1996) who found that a greater impulse is required for a shot from a greater distance. Thus the movement of the CoM slows down or even stops and the shift towards the basket at the time of landing is smaller than in the case of the 2nd distance. Even though the ball release occurs before the achieved maximum height of the CoM (Table 2) (which is how the subjects try to transfer the linear momentum from their legs to their arms (Elliot, 1992; Knudson, 1993)), the subjects obviously fail to develop enough impulse with their legs. Consequently, a stronger angular impulse of the torque with the arms is required which probably negatively affects the success of a shot at the basket. It has been suggested that a greater impulse reduces the accuracy of a shot at the basket (Miller and Bartlett, 1996; Okazaki et al., 2008).

The third co-ordinate which is not discussed in the two-dimensional plane is the co-ordinate in the direction of the baseline on the basketball court. In our study, this co-ordinate is represented by the lateral direction. It is most obvious for this direction that, where a shot is made from a longer distance, the shooting technique changes. The movement of the CoM in the direction lateral from basket starts mostly to the right, in relation to the left foot (on the assumption that the subjects shoot with their right arm), whereas before the take-off it moves mostly to the left. The take-off from this distance occurs on average 7 cm to the left from the starting position of the shot.

It is suggested that the physically weaker players use different rotations in their shoulder and hip joints when shooting from the longest distance, but these probably do not strongly influence the movement of the CoM. A stronger influence on the movement of the CoM in the lateral direction is probably exerted by the position of the hands and the ball before the shot and/or the technique in the initial phase of the shot, which explains the initial shift to the right. If, before making a shot, a player holds the ball at the hip and not in front of them, the ball performs a shorter action (Table 1) and thus covers a longer distance, resulting in a higher speed. It is possible that this movement contributes to greater shifts to the right. It would be interesting to know whether such a shift in the lateral direction occurred at the distance of 6.25 m which was valid for a three-point shot before 2010. It is highly probable that, after the rule was amended and the three-point line was moved backwards, young basketball players with less muscular strength have had to change their shooting technique and help themselves with additional movements in the lateral direction.

In the vertical direction there are some differences in the 2nd phase of the shot which is probably a consequence of the jump height. The maximum and release height of the CoM decreases with an increasing distance which is also proven by other studies (Miller and Bartlett, 1993; Erčulj and Supej, 2006). At the moment the ball is released the differences in the height are smaller because the ball release occurs at a different level of the curve of the flight of the CoM which concurs with the findings of Miller and Bartlett (1993) and Podmenik, Supej and Erčulj (2011). During shots from the shortest distance, the ball release occurred after the maximum jump height had been achieved, in the case of the medium distance the ball was released at the highest point of the jump, whereas during shots from the longest distance it was released even before a player had achieved the highest point of the jump. These findings also explain the differences between the distances in terms of time (Table 1), where the time of the beginning of the shot and take-off decreases with an increasing distance in relation to the ball release, and the time to landing increases. The results are consistent with the studies of Miller and Bartlett (1993; 1996).

As mentioned, due to the desire to transfer the linear momentum from the legs to the arms, the release is faster in the case of long distances in relation to the maximum height of the jump (Elliot, 1992; Knudson, 1993). However, on the other hand, such a strategy decreases the stability of a shot as the conditions at the moment of maximum height are the most constant (Oudejans et al., 2001). This theory is put under question in our study as the ball release in the shot from the shortest distance (3.75 m) occurs on average 0.05 s after the maximum height of the CoM is achieved (Table 2). During shots from the shortest distance (where the aspect of strength is not questionable) the release is not co-ordinated with the highest point of the jump but occurs with some delay. Thus the players acquire additional time in the air. It is possible that the players employ such a shooting strategy because they fear a defence player might block their shot. Regardless of the reason they decide on such a shot, it is a fact that the players have automated such a shooting strategy and also shoot in such a way in the absence of a defence player.

The main limitation of this study was in the flight phase. Despite its importance, this phase only consists of 15 parts (data). Due to the short interval, it would be more appropriate to use a technology that enables higher data capturing frequency. Also it is possible that the gloves that subjects wore influenced the results, although the subjects did not report, that the MVN suit was a disturbing factor. We must also take into account that subjects at the beginning of the research had some additional time to adjust.

CONCLUSIONS

There are statistically significant differences between young basketball players in terms of movement of the CoM with an increasing distance from the basket, regardless of the shooting style. Coaches should thus understand that it is impossible to expect young basketball players to maintain the same movement pattern when shooting from various distances and consider this fact in the training of young basketball players. It is also impossible to expect they will apply the same shooting kinematic (technics) as top adult players. The study shows at which levels and to what extent the changes should occur, while still preserving the same shooting accuracy.

Of course one should be aware that certain deviations from the model values are possible in individual young basketball players, and they are also presented in the study. These are mainly the consequence of the differences in the players' physical and motor development and/or the level of their physical characteristics and motor abilities (especially strength). Coaches should also be aware that the shooting kinematics (technique) of young basketball players should constantly be modified and adjusted to their physical and motor development. As can be seen from our study is this particularly true for a long-distance shot. Excessive insistence on a specific shooting technique can lead to stereotypes which a basketball player finds difficult to change at a later time so as to achieve the level of the shooting technique that enables them to develop into an elite basketball player.

ACKNOWLEDGMENTS

This study was conducted within the framework of the research programme "Kinesiology of the Monostructural, Polystructural and Conventional Sports" under the leadership of Milan Čoh, PhD.

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