

THE IMPACT OF PROGRESSIVE PHYSIOLOGICAL LOADS ON ANGULAR VELOCITIES DURING SHOOTING IN BASKETBALL – CASE STUDY

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Abstract

The main objective of this research was to determine whether progressive physiological load affects changes in certain kinematic parameters while performing jump shots in basketball. This study primarily examined the effect of fatigue on changes in angular velocities of joints of the lower and upper extremities, however, the relationship of the mentioned parameters in terms of the ultimate outcome, i.e. the duration of the shot, as well as the precision of the shot were likewise studied. The research included one examinee who is a member of the Croatian U18 Men's National Team. The study incorporated a precisely determined protocol according to which the following parameters were determined: angles of the knee and hip joint at the moment of receiving the ball, maximum and average angular velocity in the ankle, knee, hip, shoulder, elbow and wrist joint, height at the moment of releasing the ball, duration of the shot, angle at which the ball enters the basket and shooting percentage. The obtained results indicate certain differences in angular velocities of the upper and lower extremities, as well as in the height at the moment of releasing the ball under the influence of progressive fatigue. Kinematic parameters affecting the ball (duration of the shot and the angle at which the ball enters the basket) demonstrated no significant variations, however there was a significant change of the shooting percentage.

Key words: *basketball; jump shot; physiological load; SIMI motion system; kinematic analysis*

Introduction

Considering that basketball is a very dynamic sport which includes different types of running (short and longer sprints), accelerations, decelerations, jumping, landing and physical contacts with team players and opponents, it is implied that during practices and competitions basketball players undergo discontinued physiological loads that are occasionally of extremely high intensity. The conclusion can be made that whether it is women's or men's competitions, or during competitions for younger age categories, basketball players are exposed to high physiological loads (McInnes et al., 1995; Matthew & Delextrat, 2009; Abdelkrim, El Fazaa & El Ati, 2007). Upon increasing the intensity and entering the anaerobic load zone, the concentration of lactic acid in the blood increases, which ultimately effects the gradual occurrence of fatigue in the organism of basketball players (Allen, Lamb & Westerblad, 2008). This in turn results with the presumption that players perform specific motor movements when playing under the influence of higher fatigue (Rodriguez-Alonso et al., 2003). Consequently, it is to be expected that in such conditions the performance of stereotypical and

automatized movements usually performed by a basketball player shall also be modified.

The jump shot is one of the most common way of shooting in basketball (Hay, 1985). It represents the base in hierarchical structure of basketball game knowledge (Trninić, Trninić & Jelaska, 2010). The main characteristic of the mentioned element is the fact that it enables shooting the ball towards the basket from greater distances. As such, this element of basketball technique was a result of the players' desire and need to find the best solutions in new situations. Given the fact that the primary aim in basketball is to score a basket, this element became one of the most significant elements of technique in modern basketball (Hess, 1980). There has been many research of the jump shot in terms of biomechanical analysis, that is in terms of performing the mentioned motor task (Podmenik et al., 2017). Rojas et al., (2000) studied the modification of performing the jump shot technique during the active play of the defensive player. Many researches was also conducted on the effect of increasing the distance from which the jump shot is realized on the motor performance of the jump shot (Podmenik et al., 2017; Okazaki & Rodacki, 2012).

Okazaki et al. (2007) also examined the relationship between the duration of the jump shot and efficiency which resulted in a small statistically significant correlation ($r=0,22$; $p>0,05$). Erčulj & Supej (2009) studied the influence of fatigue on performing the jump shot from the 6,25 m distance, with a top shooter of NBA quality level as the subject of their research, and they managed to prove that the technique of performing the mentioned element changes under the influence of fatigue. Likewise, similar results were obtained in other research which demonstrated that certain kinematic parameters are altered during the performance of the jump shot under the influence of fatigue (Rupčić et al., 2015). Kinematic changes in performing different motoric tasks under the influence of fatigue was also noticed in some other sports (Becker et al., 2017). So far, most of performed researches included senior players. There is a need to determine if shooting training in real, situational conditions, especially while the players are under the influence of fatigue will produce better results.

The aim of this research is to precisely determine if there are statistically significant differences in kinematic parameters of young basketball players during shooting while in different stages of fatigue.

Methods

As part of this research there was one participant, a basketball player (age = 17yr) who is a member of the Croatian U18 Men's National Team. Subject was healthy and gave written consent for testing procedure. In order for each pass towards the player to be standardized in terms of its accuracy, the Dr Dish Basketball Shooting Machine® was used in this research. The shooting machine was placed under the basket and programmed to pass the ball towards the players in time intervals of 10 seconds. In order to determine the duration of the shot and the shooting angle the 94 Fifty® Smart Sensor Basketball by Infomotion Sports Technologies Inc. was used in this study. The mentioned ball is of standard size and weight which correspond with the official propositions proscribed by FIBA. In addition, on the basis of previous research this device demonstrates validated and objective results and, as such, can be used for scientific purposes (Rupčić, Antekolović, Knjaz, Matković, Cigrovski, 2017).

For the purpose of creating a kinematic pattern during the jump shot the SIMI Motion system with eight cameras was used (Basler SCA 640GC; 100 images per second) and it was in a semi-circular position under the basket. For the purpose of kinematic analysis 16 markers were placed on the examinee's body in anatomically referential points according to the modified Dempster model (Winter, 1990): 1 and 2) fifth metatarsal joints, 3 and 4) lateral malleolus of the fibula, 5 and 6) lateral condyles of the tibia, 7 and 8) greater trochanters, 9 and 10) acromion, 11 and 12) lateral epicondyles, 13 and 14) distal radials, 15 and 16) fifth metacarpal joints.

Description of the variables:

KNEEangle_{catch} (°) – angle of the knee joint at the moment of receiving the ball;

HIPangle_{catch} (°) – angle of the hip joint at the moment of receiving the ball;

ANKLEmax_angle_{vel} (°/s) – maximum angular velocity of the ankle;

KNEEmax_angle_{vel} (°/s) – maximum angular velocity of the knee joint;

HIPmax_angle_{vel} (°/s) – maximum angular velocity of the hip joint;

SHOULDERmax_angle_{vel} (°/s) – maximum angular velocity of the shoulder joint;

ELBOWmax_angle_{vel} (°/s) – maximum angular velocity of the elbow joint;

WRISTmax_angle_{vel} (°/s) – maximum angular velocity of the wrist;

ANKLEaver_angle_{vel} (°/s) – average angular velocity of the ankle;

KNEEaver_angle_{vel} (°/s) – average angular velocity of the knee joint;

HIPaver_angle_{vel} (°/s) – average angular velocity of the hip joint;

SHOULDERaver_angle_{vel} (°/s) – average angular velocity of the shoulder joint;

ELBOWaver_angle_{vel} (°/s) – average angular velocity of the elbow joint;

WRISTaver_angle_{vel} (°/s) – average angular velocity of the wrist;

Pointofrelease (m) (°/s) – highest point at the vertical line in the release of the ball;

Shooting angle (°) – angle formed by the downward line of the ball in relation to the basket;

Time of shooting (s) – time between the moment of receiving the ball and the moment in which the ball leaves the hand.

The examinee performed 30 jump shots from the 6.75 m distance as warm-up, as well as a dynamic stretching before starting with the testing. The examinee then executed three series of jump shots, each consisting of 8 shots from the previously mentioned distance. Prior to the initial testing, the lactic acid concentration of the examinee was measured after which the examinee started performing the jump shots.

Before the second series of shooting, the examinee executed continued sprints of 4x15 meters (total of 60 meters) with a change of direction of 180 degrees between each sprint, and before the third, last series, he performed continued sprints of 8x15 meters (total of 120 meters), also with a change of direction of 180 degrees between each sprint.

Immediately, after the both series of sprints, his blood lactate concentration was determined using a portable lactate analyzer (Lactate Pro LT-1710, Arkray KDK Corporation, Shiga, Japan) and then the examinee started with performing the jump shots. The mentioned type of sprint was used to attain physiological load of the player because this type of movement is often present in modern basketball game during many fast changes between defence and offense.

In order to analyse the obtained data, the Statistica for Windows, ver. 12 was used. For each of the variables the basic descriptive statistical parameters (arithmetic mean, standard deviation) were calculated, whereas the occurrence of statistically significant differences was established by applying the ANOVA for repeated measurements. Partial eta-

squared (η^2p) will be used as a measure of effect size. For the purpose of determining statistically significant differences in a single variable between the three measurements, Tuckey post hoc tests were thus employed. The $p < 0,05$ criterion was used for establishing statistical significance.



Figure 1-2. Player during the performance of a jump shot

Results

Table 1 demonstrates the basic descriptive statistical parameters of the observed variables in all three series of jump shots (initial, 4x15 m and 8x15 m), as well as the univariant analysis of variance. Out of the 17 examined variables, statistically significant differences were recognized in 8 variables (KNEEanglecatch, HIPanglecatch, SHOULDERmax_anglelevel, WRISTmax_anglelevel, ANKLEaver_anglelevel, KNEEaver_anglelevel, WRISTaver_anglelevel, Pointofrelease).

As expected, maximum deviations in relation to the initial conditions were recorded in the final measurement, when the examinee was exposed to the 8x15 meters sprint exercise, which is also demonstrated by the measured level of lactic acid concentration in the blood of 11,00 mmol/L (Tables 2 and 3).

Table 1. Basic descriptive statistical parameters, ANOVA for the repeated measurements with partial eta-squared of the observed variables in the first, second and third series

Variable	1stseries AM±SD	2ndseries AM±SD	3rdseries AM±SD	F	p	η^2p
KNEEanglecatch	131.32±0.93	131.21±1.20	136.44±3.62	13.91	0.00	0.56
HIPanglecatch	131.13±4.93	131.85±2.03	139.16±3.63	11.39	0.00	0.52
ANKLEmax_anglelevel	725.04±51.21	701.91±49.75	718.86±65.22	0.37	0.70	0.03
KNEEmax_anglelevel	563.19±12.63	564.81±19.54	573.78±38.56	0.38	0.69	0.03
HIPmax_anglelevel	357.02±11.88	354.82±13.61	359.94±20.99	0.21	0.81	0.02
SHOULDERmax_anglelevel	510.89±22.10	504.57±9.65	484.46±18.56	4.94	0.02	0.32
ELBOWmax_anglelevel	750.02±24.09	721.42±35.19	717.39±21.76	3.31	0.06	0.24
WRISTmax_anglelevel	1227.02±143.73	934.88±66.76	950.04±53.23	23.23	0.00	0.69
ANKLEaver_anglelevel	320.57±14.78	312.78±17.82	365.37±19.23	21.35	0.00	0.67
KNEEaver_anglelevel	324.69±2.59	315.69±11.38	325.67±6.93	3.94	0.04	0.27
HIPaver_anglelevel	171.24±8.29	181.90±6.90	171.74±12.23	3.26	0.06	0.24
SHOULDERaver_anglelevel	305.38±12.87	303.21±9.95	291.31±14.84	2.84	0.08	0.21
ELBOWaver_anglelevel	366.89±21.85	351.78±27.55	346.32±11.69	1.98	0.16	0.16
WRISTaver_anglelevel	423.47±77.23	325.50±33.39	327.54±19.24	10.10	0.00	0.69
Pointofrelease	2.58±0.02	2.48±0.01	2.47±0.02	150.29	0.00	0.93
Shootingangle	41.38±1.92	40.75±0.89	41.25±1.83	0.33	0.72	0.03
Timeofshooting	0.80±0.04	0.78±0.03	0.79±0.01	0.45	0.64	0.04

Legend: KNEEangle_{catch} - angle of the knee joint at the moment of receiving the ball; HIPangle_{catch} - angle of the hip joint at the moment of receiving the ball; ANKLEmax_angle_{vel} - maximum angular velocity of the ankle; KNEEmax_angle_{vel} - maximum angular velocity of the knee joint; HIPmax_angle_{vel} - maximum angular velocity of the hip joint; SHOULDERmax_angle_{vel} - maximum angular velocity of the shoulder joint; ELBOWmax_angle_{vel} - maximum angular velocity of the elbow joint; WRISTmax_angle_{vel} - maximum angular velocity of the wrist; ANKLEaver_angle_{vel} - average angular velocity of the ankle; KNEEaver_angle_{vel} - average angular velocity of the knee joint; HIPaver_angle_{vel} - average angular velocity of the hip joint; SHOULDERaver_angle_{vel} - average angular velocity of the shoulder joint; ELBOWaver_angle_{vel} - average angular velocity of the elbow joint; WRISTaver_angle_{vel} - average angular velocity of the wrist; Pointofrelease - highest point at the vertical line in the release of the ball; Shooting angle - angle formed by the downward line of the ball in relation to the basket; Time of shooting - time between the moment of receiving the ball and the moment in which the ball leaves the hand, 1st series - initial testing; 2nd series - second series of shooting after 4x15 meters sprints; 3rd series - third series of shooting after 8x15 meters sprints; AM±SD - arithmetic mean±standard deviation; F - F test; p-level: p<0,05; η²p - partial eta-squared.

Table 2. Tukey post hoc test of the following variables: angle of the knee joint and the hip joint at the moment of receiving the ball; maximum angular velocity of the shoulder joint and the wrist; average angular velocity of the ankle, the knee joint and the hip joint.

KNEEangle _{catch}			
sel	{1 st series} 131.32	{2 nd series} 131.21	{3 rd series} 136.44
2 nd series	0.99		
3 rd series	0.00	0.00	
HIPangle _{catch}			
sel	{1 st series} 131.13	{2 nd series} 131.84	{3 rd series} 139.16
2 nd series	0.92		
3 rd series	0.00	0.00	
...			
SHOULDERmax_angle _{vel}			
sel	{1 st series} 510.89	{2 nd series} 504.57	{3 rd series} 484.46
2 nd series	0.75		
3 rd series	0.01	0.07	
WRISTmax_angle _{vel}			
sel	{1 st series} 1227.0	{2 nd series} 934.88	{3 rd series} 950.04
2 nd series	0.00		0.94
3 rd series	0.00	0.94	
ANKLEaver_angle _{vel}			
sel	{1 st series} 320.57	{2 nd series} 312.78	{3 rd series} 365.37
2 nd series	0.64		0.00
3 rd series	0.00	0.00	
KNEEaver_angle _{vel}			
sel	{1 st series} 324.69	{2 nd series} 315.69	{3 rd series} 325.67
2 nd series	0.07		0.04
3 rd series	0.96	0.04	
WRISTaver_angle _{vel}			
Sel	{1 st series} 423.47	{2 nd series} 325.50	{3 rd series} 327.54
2 nd series	0.00		
3 rd series	0.00	0.99	

Legend: KNEEangle_{catch} - angle of the knee joint at the moment of receiving the ball; HIPangle_{catch} - angle of the hip joint at the moment of receiving the ball; SHOULDERmax_angle_{vel} - maximum angular velocity of the shoulder joint; WRISTmax_angle_{vel} - maximum angular velocity of the wrist; ANKLEaver_angle_{vel} - average angular velocity of the ankle; KNEEaver_angle_{vel} - average angular velocity of the knee joint; WRISTaver_angle_{vel} - average angular velocity of the wrist; 1st series - initial testing; 2nd series - second series of shooting after 4x15 meters sprints; 3rd series - third series of shooting after 8x15 meters sprints; p-level: p<0.5

As presented in Table 3 it is obvious that lactate values significantly increased during the testing. From very low values of 0.9 mmol/L before the first shooting series, which corresponds to resting state, after 4x15 m sprint lactate concentration increased to 1.7 mmol/L, and after two shooting series and 8x15m sprints it was as high as 11.0 mmol/L.

Table 3. Indicators of shooting efficiency and level of lactates after all three measurements

variable	1 st series	2 nd series	3 rd series
Efficiency of shooting	5/8	3/8	2/8
Lactate (mmol/L)	0.90	1.70	11.00

Legend: Efficiency of shooting - the ratio between successful and unsuccessful shots; Lactate -blood lactate concentration before initial shooting (1st series) and after 4x15 meters sprint (2nd series) and 8x15 meters sprint (3rd series)

Table 4. Differences in the measured variables presented in percentages between the three levels of load

variable	1 st series	2 nd series	3 rd series	2.-1.	3.-2.	3.-1.
ANKLEaver_angle _{vel}	320.57	312.78	365.37	-2.43%	16.81%	13.97%
KNEEaver_angle _{vel}	324.69	315.69	325.67	-2.77%	3.16%	0.30%
HIPaver_angle _{vel}	171.24	181.90	171.74	6.22%	-5.58%	0.29%
SHOULDERaver_angle _{vel}	305.38	303.21	291.31	-0.71%	-3.92%	-4.60%
ELBOWaver_angle _{vel}	366.89	351.78	346.32	-4.11%	-1.55%	-5.60%
WRISTaver_angle _{vel}	423.47	325.50	327.54	-23.13%	0.62%	-22.65%
ANKLEmax_angle _{vel}	725.04	701.91	718.86	-3.19%	2.41%	-0.85%
KNEEmax_angle _{vel}	563.19	564.81	573.78	0.29%	1.59%	1.88%
HIPmax_angle _{vel}	357.02	354.82	359.94	-0.62%	1.44%	0.82%
SHOULDERmax_angle _{vel}	510.89	504.57	484.46	-1.24%	-3.99%	-5.17%
ELBOWmax_angle _{vel}	750.02	721.42	717.39	-3.81%	-0.56%	-4.35%
WRISTmax_angle _{vel}	1227.02	934.88	950.04	-23.81%	1.62%	-22.57%

Legend:ANKLEaver_angle_{vel} - average angular velocity of the ankle; KNEEaver_angle_{vel} - average angular velocity of the knee joint; HIPaver_angle_{vel} - average angular velocity of the hip joint; SHOULDERaver_angle_{vel} - average angular velocity of the shoulder joint; ELBOWaver_angle_{vel} -average angular velocity of the elbow joint; WRISTaver_angle_{vel} - average angular velocity of the wrist; ANKLEmax_angle_{vel} - maximum angular velocity of the ankle; KNEEmax_angle_{vel} - maximum angular velocity of the knee joint; HIPmax_angle_{vel} - maximum angular velocity of the hip joint; SHOULDERmax_angle_{vel} - maximum angular velocity of the shoulder joint; ELBOWmax_angle_{vel}-maximum angular velocity of the elbow joint; WRISTmax_angle_{vel} - maximum angular velocity of the wrist; 1st series - initial testing; 2nd series - second series of shooting after 4x15 meters sprints; 3rd series - third series of shooting after 8x15 meters sprints; 2.-1. - distinction between 2nd series and 1st series; 3.-2. - distinction between 3rd series and 2nd series; 3.-1. - distinction between 3rd series and 1st series

Angular velocities in different joints during the first, second and third series of shooting are presented in Table 4. It could be seen that maximum angular velocities of the shoulder joint and wrist were significantly scaling down with the greater manifestation of fatigue (SHOULDERmax_angle_{vel} = 510.89±22.10; 504.57±9.65; 484.46±18.56, p=0.02 and WRISTmax_angle_{vel}= 1227.02±143.73; 934.88±66.76; 950.04±53.23, p=0.00) as well as the elbow maximum angular velocity (ELBOWmax_angle_{vel} = 750.02±24.09; 721.42±35.19; 717.39±21.76) where the diminution was present but not significant. At the same time shooting precision was reduced (Table 3.)

Changes in the height of releasing the ball as a result of different levels of the physiological load are presented graphically (Figure 3).

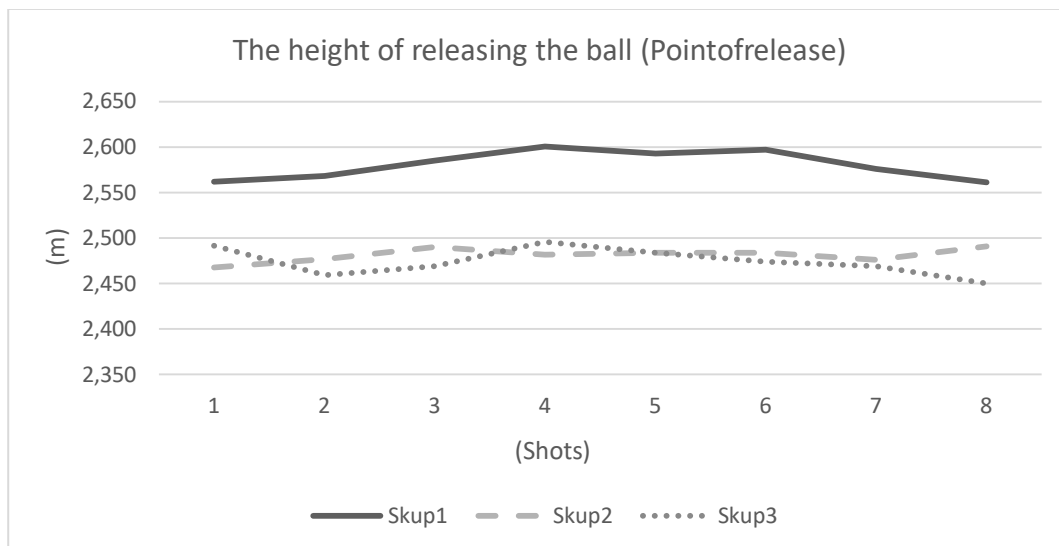


Figure 3. Changes in the height of releasing the ball as a result of different levels of load

Discussion

Upon analysis of the measured values of the knee joint and the hip joint at the moment of receiving the ball, it was noted that after greater fatigue intensity the mentioned values also increase, which thus indicates the fact that the examinee was in a more upright position at the moment of receiving the ball when exposed to a greater level of fatigue. Previous researches determined that the values of the hip and knee were decreased when shooting from larger distances, i.e. when the player performs the jump shot from larger distances, he also lowers his centre of gravity in the initial phase of the shot, which consequently leads to the flexion of joints in the lower extremities (Svoboda et al., 2016).

It is presumed that in order for a player to perform the jump shot quickly enough, without him being obstructed by the defensive player, the player must be in active position which means that his centre of gravity is adequately lowered, in addition to a certain flexion of the lower extremities. Combined with properly balanced space-time conditions of receiving the ball and using the ground reaction force, such a position is assumed to influence the correct angle of releasing the ball, and then consequently also the shooting angle which ultimately impacts the precision of the jump shot. Former research also determined a statistically significant correlation between the angle of releasing the ball and the shooting angle, as well as a causal link with precision (Lenik & Lenik, 2016; Fontanella, 2006).

Upon examining the angular velocities of joints in the upper extremities, interesting observations can be recorded. When the examinee was most tired, maximum angular velocity values of the shoulder joint and the wrist statistically significant decreased, whereas in the elbow joint the observed values also decreased, however not in a statistically significant degree.

The above-mentioned observations can also be determined by performing additional analyses of the obtained results of average and maximum angular velocities of joints in the upper extremities which lead to the conclusion that the most significant changes were recorded between the initial measurement, when the examinee was not exposed to a high load level, and the most intensive load when the lactic acid concentration in the blood was 11.0 mmol/L. Therefore, the average angular velocity in the shoulder joint was reduced by 4.60%, in the elbow joint by 5.60% and in the wrist by 22.65%. This also refers to values of maximum angular velocities, in which case the shoulder joint value was decreased by 5.17%, the elbow joint by 4.35% and the wrist by 22.57%. Tsai et al. (2006) obtained comparable results where the values of angular velocities in the elbow joint and the wrist statistically significantly decreased under the influence of higher load.

After analysing the values of angular velocities of joint in the lower extremities, it can be noted that in most cases the mentioned values increase, particularly between the second (2nd series) and third measurement (8x15m). Thus, for example, the largest difference in the average angular velocity of the ankle was recorded between the second and third measurement, and it was 16.81% ($p=0,00$), while in the maximum angular velocity values the difference was 2.41%. Upon examining the knee joint and the hip joint the differences were not statistically significant, however, they were noticeable. Tsai et al. (2006) in their research concluded that under higher level of load, the angular velocity of the hip joint decreased for 3.04% (182.44; 176.88), and in ankle joint for 1.65% (564.77; 555.40), but the angular velocity in knee joint has increased by 9.46% (279.73; 306.21).

Based on the measured kinematic parameters, the conclusion can be made that the examinee changed his usual pattern of performing the jump shot. The

above-mentioned is especially noticeable in the results of angular velocity of the wrist. It is precisely the wrist that plays an important role in the correct performance of jump shots as it produces the final "whip" when shooting the ball, which combined with the action of the fingers gives the ball the adequate speed and proper trajectory that consequently affects the precision of the shot (Fontanella, 2006). Changes in the pattern of performing the jump shot inevitably lead to changes in shooting precision. The notable decrease of shooting precision was determined. Similarly, Nezhad, Rahimi & Sarshin (2015) while studying the effects of fatigue on knee and elbow kinematics during 3 point jump shot concluded that general fatigue negatively affected shooting accuracy in young boys.

Furthermore, this research also showed a notable statistically significant difference in the height at the moment of releasing the ball. In other words, under the influence of fatigue the basketball player performs the final phase of releasing the ball at a reduced height which can ultimately result in an allowed blocking of the shot by the defensive player (Rojas et al., 2010; Borović, Rupčić & Antekolović, 2015).

The parameters that demonstrated no statistically significant changes were the speed of releasing the ball and the angle at which the ball enters the basket.

5. Conclusion

From the biomechanical standpoint, the jump shot is a complex motor movement. Upon analysis of kinematic parameters of the jump shot of the

examinee before and after the physiological load, the conclusion is made that fatigue impacts certain changes in the kinematic pattern of performing the jump shot. The angular velocities of joint in the lower extremities noticeably increased, while the mentioned parameters in the upper extremities decreased. In addition, as a result of fatigue, the height of releasing the ball also decreased. Despite the changes in the above-mentioned parameters, the action performed on the ball remained unchanged considering that the duration of the release, as well as the angle at which the ball entered the basket demonstrated no changes. Even though the action performed on the ball did not alter from the biomechanical standpoint, the reduction of shooting precision under the influence of a higher level of fatigue still suggests that certain deviations occurred in the overall pattern of performing the examined motor skill.

Based on this research, a proposal for the improvement of basketball practice is surely to perform training processes during which the jump shot and the development of shooting precision would be executed in conditions of variable load that shall ultimately be directed towards annulling the deviations in the kinematic pattern of the jump shot, which shall consequently also positively affect the development of shooting precision.

Considering that this research was conducted with only one examinee and in controlled environment, all the conclusions should be taken with caution. This research surely opens the possibility for future researches that should focus on influence of fatigue during different in game situations on shot efficiency.

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