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IMPACT OF FATIGUE ON ACCURACY AND CHANGES IN CERTAIN KINEMATIC PARAMETERS DURING SHOOTING IN BASKETBALL

UTJECAJ UMORA NA PRECIZNOST I KINEMATIČKE PARAMETRE ŠUTA U KOŠARCI

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SUMMARY

The main objective of this study was to establish whether fatigue has an effect on accuracy during basketball shooting. Aside from basketball shooting accuracy, two very important kinematic parameters were also examined as they have an effect on the level of accuracy during shooting: the speed of performing the actual shot and the angle at which the ball enters into the basket after a jump shot is performed.

In conducting this research one examinee was observed, a member of the Croatian U16 National Basketball Team. This research included a precisely defined protocol according to which the following parameters were established: the accuracy of basketball shooting (ratio between successful and missed shots), the speed of performing the shot and the angle of entry of the ball into the basket. The physiological load was determined by performing the standardised specific protocol which the examinee performed until exhaustion.

The results which were obtained indicate that there are no significant changes in the accuracy during one point, two point or three point shooting under the influence of physical fatigue. The obtained results of kinematic parameters indicate that there are statistically significant differences in the shooting speed before and after loading in two point and three point shots. During performing free throws the angle of entry of the ball into the basket changes, whereas the accuracy remains unchanged.

Keywords: basketball, shooting, physiological load, lactic acid.

SAŽETAK

Glavni cilj ovog istraživanja bio je utvrditi ima li umor utjecaj na preciznost šuta u košarci. Osim preciznosti također su analizirana i dva vrlo važna kinematička parametra za koja su dosadašnja istraživanja utvrdila utjecaj na preciznost šuta: brzina izvođenja samog šuta i kut pri kojem lopta ulazi u koš nakon skok šuta.

U provedbi ovog istraživanja sudjelovao je jedan ispitanik, član Hrvatske U16 košarkaške reprezentacije. Istraživanje uključuje precizno definiran protokol prema kojem su uspostavljeni sljedeći parametri: preciznost šuta (omjer između uspješnih i neuspješnih šuteva), brzina izvedbe šuta i kut ulaska lopte u koš. Umor je izazvan izvođenjem standardiziranog protokola fiziološkog opterećenja trčanjem koji ispitanik obavlja do iscrpljenosti.

Dobiveni rezultati pokazuju da nema značajne promjene u preciznosti šuta za jedan, dva ili tri poena pod utjecajem tjelesnog umora. Dobiveni rezultati kinematičkih parametara pokazuju da postoje statistički značajne razlike u brzini šuta prije i poslije opterećenja pri šutu za dva i tri poena. Tijekom izvođenja slobodnih bacanja kut ulaska lopte u koš se mijenja ali bez promjene preciznosti.

Ključne riječi: košarka, šut, fiziološko opterećenje, mliječna kiselina.

Introduction

Basketball is described as a complex sport game consisted of quick and frequent exchanges of defensive and offensive actions during which players perform a large number of sprints, jumps, changes of direction, lateral movements, etc. Upon analysing the intensity during a basketball game it can be concluded that the players are subjected to activities with an extremely high physiological load (8). Former studies conducted on different samples of basketball players indicate that their heart rate during a basketball game is on average at 87% of the maximal heart rate, which is 165±9 beats/min. The highest recorded heart rate was 188±7 beats/min, that is, 99±1 % of the maximal heart rate (11,13).

The recorded values of the lactic acid concentration can approximately be used to establish the energy sources which dominate during a certain type of physical activity (9). Former studies have confirmed that the players' lactic acid concentration during actual games are on average around 6.8±2.8 mmol/L, with an average maximal concentration of 8.5±3.1 mmol/L, and with individual results reaching up to 13.2 mmol/L (12). During practice games the average level of lactic acid were around 4.2±1.3 mmol/L (14).

In female basketball players the heart rates were around 165±9 beats/min on average, that is, 89.1% of the maximal heart rate, while the lactic acid concentrations in the blood were 5.2±2.7 mmol/L (10). Upon examining heart rates according to the various players positions, different results were recorded (Guard=185±5.9; Forward=175±11 and Center=167±12 beats/min), as well as in results of the lactic acid concentrations in their blood (Guard=5.7±2.1; Forward=4.2±2.1 and Center=3.9±2.0 mmol/L) (15).

It is precisely these results which were determined in various former studies that point to the fact that during a basketball game players are in an intensity zone in which their heart rates surpass the heart rate results which are recorded at the anaerobic ventilatory threshold, which results in a gradual increase of the lactic acid level and in a reduction of the intensity of the activity.

The aim of this research is to establish whether a player's fatigue which is a result of the intensity of the game has an effect on his shooting accuracy, as well as on certain basic kinematic parameters which determine the successfulness of each shot.

Methods

Sample of examinees

The study was conducted on a sample of one examinee, a member of the Croatian U16 National Team (age: 16, body height: 190 cm, body weight: 74,1 kg, position: shooting guard). Based on conducted laboratory measurements of maximal oxygen uptake and ventilator threshold it was concluded that the player has well developed general fitness (VO2MAX - 64,11 ml/kg/min, VO2ANT - 54,63 ml/kg/min, HRMAX - 195 bpm, HRANT) - 173 bpm).

Sample of variables

Our study included the following parameters: shooting accuracy (ratio between successful and missed shots), the shooting speed and the angle of entry of the ball into the basket. All the mentioned parameters were included while analysing both three point and two point shot attempts, whereas for free throws only the shooting accuracy and the angle of entry of the ball into the basket were taken into consideration. The physiological load was established by performing the standardised specific protocol which the examinee performed until exhaustion. The level of fatigue during the mentioned test was established by the means of a subjective evaluation of the examinee using the Borg scale (1-13), as well as by measuring the concentration of the lactic acid in the blood (mmol/L).

Before the testing the examinee was completely informed on the overall testing protocol and his written consent was received.

The research consisted of a specific warm up for the physical efforts to which the examinee will be subjected during the testing, followed by the initial shooting test (two point shots, three point shots and free throws), then a specific basketball test which the examinee performed until exhaustion, determining the level of loading and concluding with a final shooting test (two point shots, three point shots and free throws).

The initial, as well as the final shooting test, consisted of a total of 15 three point shots, 15 two point shots and 5 free throws. For the needs of passing the ball to the examinee the Dr. Dish Shooting Machine ® was used, specifically for the purpose of eliminating possible errors in the precision of the passes. This machine provides the possibility of defining precise time intervals between the passes, as well as defining the desired position of each pass and the intensity of the passes.

Image 1. Dr. Dish Shooting Machine ® (https://drdishbasketball.com/)
Slka 1. Košarkaški top Dr. Dish Shooting Machine ®

For the needs of determining the speed of the shots and the angle at which the ball enters into the basket the examinee used the 94 Fifty Smart Sensor Basketball® which enables the measuring of all the mentioned parameters (2).

Image 2. 94 Fifty Smart Sensor Basketball® (www.94fifty.com)
Slika 2. Košarkaška lopta sa senzorom 94 Fifty Smart Sensor Basketball®

A specific test for fatigue achievement consisted of several particular basketball elements such as running sprints, changes in direction and shooting (Image 1.). In addition, during the mentioned testing protocol the Dr. Dish Shooting Machine was also used. The rate of perceived exertion (RPE) was determined with the Borg scale ranging from 1 to 13, in which 1 indicates the lowest level of loading, whereas 13 indicates the highest level of loading, while the objective measure of the fatigue was the concentration of the lactic acid in capillary blood.

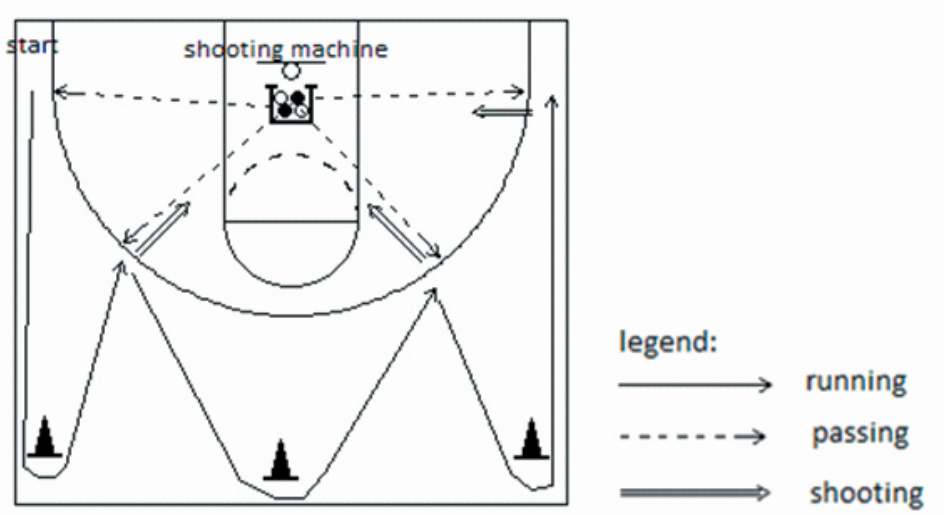

Image 3. Specific loading test until exhaustion
Slika 3. Skica testa opterećenja do otkaza

The last stage of measurements included the final shooting test in two point shots, three point shots and free throws.

Testing protocol

- warm up and dynamic stretching
- initial two point shooting (15x), three point shooting (15x) and free throw shooting (5x)
- loading test until exhaustion
- establishing the RPE and the concentration of lactic acid in the blood
- final two point shooting (15x), three point shooting (15x) and free throw shooting (5x)

Data analysis

The data analysis was performed using the software package STATISTICA for Windows, version 10th, and for each variable the following parameters were calculated: the arithmetic mean (AM), the standard deviation (SD), the minimum value (MIN), the maximum value (MAX). The differences between the initial and the final shooting results for each variable were tested by using the t-test for dependent samples.

Results and discussion

The level of physical fatigue was determined by means of the subjective evaluation of the examinee using the Borg scale (1), as well as by measuring the lactic acid concentration in the blood (mmol/L). The RPE of the examinee on the Borg scale ranging from 1 to 13 was estimated to be 12, while the lactate concentration in the blood amounted to 10,2 mmol/L. Both parameters indicated a high level of physical fatigue to which the examinee had been subjected.

Table 1. Frequencies and percentages of initial and final one point, two point and three point shooting
Tablica 1. Frekvencije i postoci inicijalnog i finalnog šutiranja na koš za jedan, dva i tri poena

Var.	$INITIAL_{FREQ.}$	INITIAL %	$FINAL_{FREQ.}$	FINAL %
1P	5/5	100	5/5	100
2P	9/15	60	10/15	66,66
3P	6/15	40	7/15	46,66

Table 2. Differences between initial and final two point and three point shooting in the angle of entry of the ball into the basket and shooting speed
Tablica 2.Razlike između inicijalnog i finalnog šuta za dva i tri poena za kut ulaska lopte u koš

Var.	Mean initial	Mean final	t-value	df	p	Valid N initial	Valid N final	Std. Dev. initial	Std. Dev. final	F -ratio	P -variances
$3P_{ANG}$	43,00	42,73	0,29	28	0,76	15	15	2,85	2,01	2,00	0,20
$3P_{SPE}$	**85,60**	**91,40**	**-2,84**	**28**	**0,00**	**15**	**15**	**4,61**	**6,40**	**1,92**	**0,23**
$2P_{ANG}$	44,46	42,46	1,68	28	0,10	15	15	3,22	3,29	1,04	0,94
$2P_{SPE}$	**82,06**	**88,73**	**-2,54**	**28**	**0,01**	**15**	**15**	**6,29**	**7,95**	**1,59**	**0,39**

Table 3. Differences between initial and final free throw shooting in the angle of entry of the ball into the basket
Tablica 3.Razlike između inicijalnog i finalnog slobodnog bacanja za kut ulaska lopte u koš

Var.	Mean initial	Mean final	t-value	df	p	Valid N initial	Valid N final	Std. Dev. initial	Std. Dev. final	F -ratio	P -variances
$1P_{ANG-IN/FIN}$	**48,00**	**39,00**	**3,61**	**8**	**0,00**	**5**	**5**	**4,00**	**3,70**	**1,16**	**0,88**

Upon analysing the obtained results of kinematic parameters while performing a two point or three point jump shot (the angle of entry of the ball into the basket and the shooting speed) and free throws (the angle of entry of the ball into the basket), which were measured using the 94 Fifty Smart Sensor Basketball ®, the conclusion can be made that there are statistically significant differences in the shooting speed before and after loading in two point ($2P_{SPE}$) and three point ($3P_{SPE}$) shots ($2P_{SPE\ initial}$ 0,82 sec - $2P_{SPE\ final}$ 0,88 sec (p=0,00); $3P_{SPE\ initial}$ 0,85 sec - $3P_{SPE\ final}$ 0,91 sec (p=0,01)), whereas there are no statistically significant differences in the angle of entry of the ball into the basket while performing two point ($2P_{ANG}$) and three point ($3P_{ANG}$) shots ($2P_{ANG\ initial}$ 44,46° - $2P_{ANG\ final}$ 42,46° (p=0,10); $3P_{ANG\ initial}$ 43° - $3P_{ANG\ final}$ 42,73 (p=0,76)) (Table 2.).

On the other hand, the parameters measured during free throws lead to the conclusion that under the impact of fatigue the angle of entry the ball into the basket changes, whereas the shooting accuracy remains unchanged ($1P_{ANG\ initial}$ 43,90° - $1P_{ANG\ final}$ 39,60° (p=0,01)). It is assumed that one of the reasons due to which the accuracy of performing free throws remained unchanged is the fact that the examinee performed these shots in a very close range of ideal angle for shooting the ball into the basket (46,7°) and the statistically significant change in the shooting angle did not have a direct effect on the demonstrated accuracy (4) (Table 3.). Also, Satti in his research had similar results (37,8-42,0°) during performing free throws also with a high level of accuracy (16).

When performing a jump shot, both of these kinematic parameters (angle and speed) are important elements from the aspect of a player's situational efficiency during a game. The angle at which the ball enters into the basket is determined to be an exceptionally important regression factor in shooting accuracy. According to certain authors, the following basic variables are what determine the shooting accuracy: the player's distance from the basket, the position of the defence and the angle at which the ball enters into the basket (5,7). Surely, a number of other elements also determine the shooting accuracy, such as the quality of executing motor skills – shooting technique (correctly shooting the ball, holding and controlling the ball, the rhythm of performing the shot, etc.), visualization and spatial perception of the „target“ – the basket, motor predispositions (explosive strength of the legs, arms and shoulders, general body coordination, balance, precision) and psychological characteristics (concentration, self-confidence).

When comparing the obtained results from both the initial and final shooting (2P and 3P), the conclusion can be made that the angle at which the ball enters into the basket decreases as a result of fatigue, however, its reduction is not statistically significant. From the aspect of biomechanical analysis of the jump shot and the adaptability of the human body to the mentioned motor movement, a majority of authors believe that the angle of entry of the ball into the basket should be around 45° (4,6).

Upon analysing the measured angles in both shooting tests (initial and final), that is, after examining them in terms of the above mentioned statements, we can conclude that our examinee demonstrated borderline results in terms of the mentioned kinematic parameter. The errors which typically result in a lower angle of entry of the ball into the basket are the insufficient lifting of the elbow in the central jump shot position (the elbow is not directed towards the basket), the lack of coordination between the movements of the arms and legs, the insufficient exploitability of the reaction force of the surface, etc.

In addition, the results demonstrated in Table 4. also give proof of the importance of the correct angle at which the ball enters into the basket, as it is precisely these results that clearly indicate the existence of statistically significant differences between successful and missed two point and three point shots, that is, they demonstrate that the angle of entry of the ball into the basket was higher in successful shots, as it was closer to the ideal borderline results.

Table 4. Differences between successful and missed two point and three point shots in the angle of entry of the ball into the basket

Tablica 4.Razlike između uspješnog i neuspješnog šutiranja za dva i tri poena za kut ulaska lopte u koš

Var.	Mean succ.	Mean miss.	t-value	df	p	Valid N initial	Valid N final	Std. Dev. initial	Std. Dev. final	F -ratio	P -variances
$2P_{ANG}$	44,52	41,63	2,45	28	0,02	19	11	3,06	3,17	1,07	0,85
$3P_{ANG}$	44,30	41,76	3,28	28	0,00	13	17	1,54	2,43	2,47	0,11

Conversely, the variable which demonstrated statistically significant differences between the initial and final shooting test under the influence of physical fatigue is the speed of performing a two point and three point jump shot. The time interval which is expressed as the shooting speed is the period between the moment in which the player catches the ball and the moment in which the ball leaves his hand, which was calculated by using the 94 Fifty Smart Sensor Basketball. In modern basketball the importance of the shooting speed represents a factor of an extremely great value, as players are becoming more physically conditioned and prepared, as well as more technically and tactically skilled, this means that the defence more rapidly adapts to new situations, which then makes it obvious that the time interval during which a player can prepare for shooting the ball towards the basket is gradually decreasing. The progressive increase of the time interval between receiving the ball and shooting it towards the basket as a result of fatigue can very often be caused by a poorer phase of preparation for receiving the ball, that is, as players get more tired they tend to rely more on the movement of the arms during the shot, and less on the adequate preparation of the entire body (a lower shooting position), especially of the legs. Likewise, another significant factor is the poor exploitability of the reaction force of the surface, so that immediately after receiving the ball the player cannot perform a vertical take-off and lift the ball towards the central jump shot position, but he rather attempts to compensate for the absence of the above mentioned technique by lowering the ball and in that manner, by creating an impetus arm impulse, providing himself with an ideal angle for shooting the ball.

According to certain studies, as a result of a higher level of physical fatigue, the player performs the jump shot with a decreased vertical take-off, which consequently implies that this lower vertical take-off is a result of the exhaustion of the lower extremity muscles (3), which then most likely also affects the above mentioned kinematic parameters, such as the shooting speed and the entry angle of the ball into the basket.

Conclusion

Jump shot drills in basketball can be performed in order to achieve energetic (physiological), psychological or biomechanical improvements. If each training unit is desired to result in positive effects, especially in jump shot drills, it is necessary for the players to perform a certain number of such training units in realistic situational circumstances. A high shooting accuracy, an ideal shooting speed and angle of entry of the ball into the basket which are not performed under a loading level which is similar to a realistic course of a basketball game does not improve or enhance the player in the full sense.

It is a widespread perception that the more exhausted a player is, the less accurate he becomes. However, the results of this study, as well as the results of previous research, refute that hypothesis. The assumption is that players have automatized their shooting to the point that the impact of fatigue results in a decrease of the shooting speed, as well as the entry angle of the ball into the basket which will be lower than the ideal 45°, however, the shooting accuracy will not significantly change.

The technology which was used in our research also provides a significant contribution to the mentioned scientific conclusions, but also to the progress of the practice itself. The subjective evaluation of the coach no longer remains the only criterion, as now there are objective measurements which can either confirm or contradict his subjective assessment. To be sure, these measurements still only serve as a secondary means in the performance of a basketball coach.

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