Original Article

Dependence of basketball repulsion on the pressure within this sport

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Abstract:
The aim of this research is to determine the elastic (repulsive) properties of basketballs depending on the air pressure in it. Basketball of standard dimensions was released on the flat solid surface from the height of nine meters for four times. At the first release the air in the ball was under prescribed pressure. At the second release the pressure in the pumped ball is reduced by 5%, at the third reduced by an additional 5%, at the fourth reduced by another 5%. The setting of the experiment was carried by cinema shooting of free fall of the prescribed basketball and a series of rebounds after the rejection of solid surfaces. One can conclude that the distance crossed and the total duration of four successive bouncing mostly dependent on inner pressure. In this study, the initial speed of a basketball was unchanged and only inner pressures were changed. It was determined how much the height of the rebound is reduced and the duration of the rebound, respectively, depending on the reduction of inner pressure. Overall, it can be concluded that the initial speed of the ball can be increased by increasing the inner pressure in the ball.
Key words: basketball, pressure in basketball, repulsion

Introduction

Within physical development program the games have a dominant role, and among all games the most important are the ball games. In our environment the basketball occupies one of leading roles when the ball games are in focus. The most important equipment of these games is ball (Karimi et al., 2015). Today, all kind of balls are produced whose construction has been getting closer to full symmetry, but the ideal symmetry of the ball has not been reached yet!

Basically, the football match is, strategically speaking, the battle for space and time. Those are the most important components in the ball games. Ball sports such as basketball place large metabolic demands on players (Hatamoto et al., 2014). In a good match, each player makes a lot of elementary muscular contractions at the field, providing a series of complex movements, in a struggle to come into possession of the ball before the opponent player, to enter the zone from where the score can be reached before being distracted by the opponent player. Since such maneuver takes place continuously and it is time-consuming, furthermore the modern maneuver, where there are already well-coordinated combinations, is being performed in the highest speed and in a state of maximum fatigue, each good basketball game maximally exhaust all players at the field.

The result of a basketball game is not been assessed by the level of motor performance nor who ran longer, or who is running faster, or who has jumped more, but by the number of points scored. Therefore, all maneuvering movements during a game are subordinated to the ball movement. Ball is a machine, whose properties each player must be fully aware of (Bjelica, 2008). This is the primary reason why every player must be fully aware of the nature of the elastic properties of a basketball. The aim of this research is to determine the elastic (repulsive) properties of basketballs depending on the air pressure in it, which basically fall under the kinematic researches.

Material & Method

Research conducted in this study primarily refers to the standard basketball for seniors with the following performances (Table 1.):

Table 1. Dimensions of basketball

Weight (kg)	Radius (m)	Circumference (m)	Cross-section (m^2)	Surface (m^2)	Capacity (m^3)
0.625	0.1215	0.7634	0.04638	0.1855	0.0075

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Recently, sophisticated finite element models of sports ball impacts have been developed for various sports (Nevinsa & Smitha, 2013). A standard basketball with full symmetry was acquired from the licensee manufacturer. Both layers, one of which is required to construct a ball, have inevitable flaws, affecting the appearance of asymmetry, not huge but enough to cause changes, which do not exist in the ideal spherical body. Since in the cavity of the inner layer has to be pumped the air, there must be a valve, which, no matter how small is represents the asymmetry of the ball.

Basketball of standard dimensions was released on the flat solid surface from the height of nine meters for four times. The flight of a ball through the air is a key part of many popular sports (Barber, 2009). At the first release the air in the ball was under prescribed pressure – p (Table 2.). At the second release the pressure in the pumped ball is reduced by 5% - p1 (pressure prescribed minus 5%, Table 2.). At the third release the pressure in the pumped ball is reduced by an additional 5% - p2 (pressure prescribed minus 5%, minus 5%, Table 2.) At the fourth release the pressure in the pumped ball is reduced by another 5% - p3 (pressure prescribed minus 5%, minus 5%, minus 5%, Table 2.) By calibrated gauge pressure the internal pressures were respectively measured.

Table 2. Air pressure in the basketball

(p) Prescribed	(p1) reduced by 5%	(p2) reduced by 5%	(p3) reduced by 5%
0.65	0.6175	0.5865	0.5575

A rather demanding calculation of repulsions coefficient value was made with one of the basic programs. The setting of the experiment was carried by cinema shooting of free fall of the prescribed basketball and a series of rebounds after the rejection of solid surfaces. The recording was performed with the rapid-professional digital movie camera JVC GY-HM750E with fifty shots per second and the exposure sec/100. During the shooting, the camera was completely immobilized. In the projection of basketball movement the markers were measured (in meters), in order to determine the extent (R) between the size of the screen and the real size (R-size screen natural). During the research the area of the collision was determined by transmission contrasting colors of the ball and surface before the collision with the ground and measuring the surface impressions on the ball and the ground after the rebound. The duration of the movements is measured in seconds, i.e. every fifty positions lasted one second and the duration between two neighboring positions lasted sec/50. The processing took positions of falls of each ball and its four rebounds.

Results and Discussion

Table 3. shows a global view of spatiotemporal parameters of repulsion of basketball with full symmetry depending on the air pressure in it.

Table 3. Spatiotemporal parameters of repulsion of basketball with different air pressures

	parameters	Pressure of the ball			
		p	p1	p2	p3
h1	Height of free fall (m)	9	9	9	9
t1	Duration of the first fall (s)	1.04	1.08	1.08	1.10
t2	Duration of the first climbing (s)	0.68	0.60	0.58	0.60
h2	Height of the first rebound (m)	3.15	2.77	2.81	3.07
t3	Duration of the second fall (s)	0.64	0.60	0.62	0.64
t4	Duration of the second climbing (s)	0.56	0.40	0.38	0.42
h3	Height of the second rebound (m)	1.47	1.26	1.26	1.51
t5	Duration of the third fall (s)	0.44	0.38	0.40	0.42
56	Duration of the third climbing (s)	0.30	0.28	0.28	0.32
h4	Height of the third rebound (m)	0.84	0.76	0.71	0.84
t7	Duration of the fourth fall (s)	0.32	0.28	0.28	0.30
t8	Duration of the fourth climbing (s)	0.24	0.20	0.22	0.24
h5	Height of the fourth rebound (m)	0.50	0.42	0.50	0.48

At the first phase, the diagrams 1, 2, 3 and 4 shows the basketball paths with spatiotemporal parameters in the first four rejections of solid surface, depending on the air pressure in it. In the vertical, there are culmination points of each rejection of the surface, measured in meters, and in the horizontal the length of each rejection of the surface is shown in seconds.

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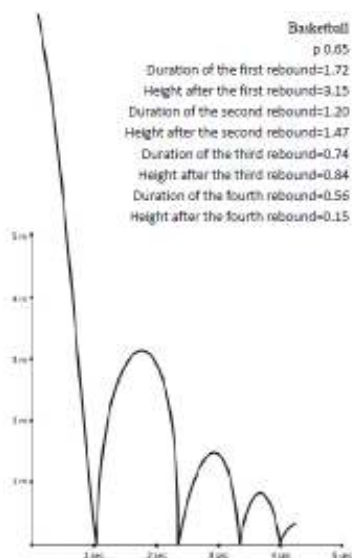*JPES* ®   www.efsupit.ro

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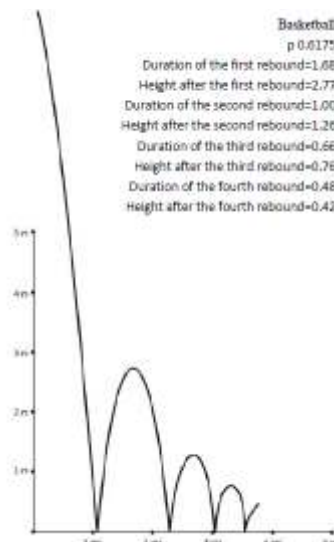
Diagram 1. Time and height of rebound for p

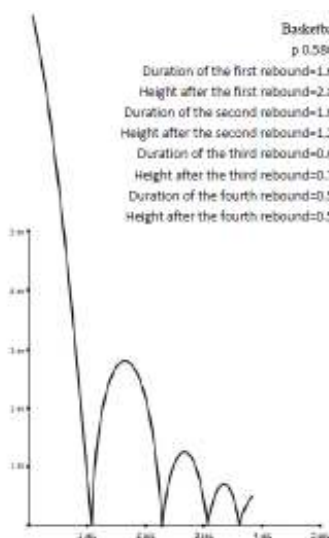Diagram 2. Time and height of rebound for p1

Diagram 3. Time and height of rebound for p2

Diagram 4. Time and height of rebound for p3

At the second phase it was carried out the interpolation of diagrams of duration of individual rebounds in a function of distance covered on diagrams 5, 6, 7 and 8, as well as interpolation of diagrams of culmination points of individual rebounds over the time in diagrams 9, 10, 11 and 12 with the entered data.
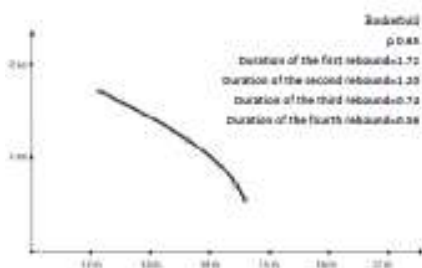

Diagram 5. Duration of rebound for p
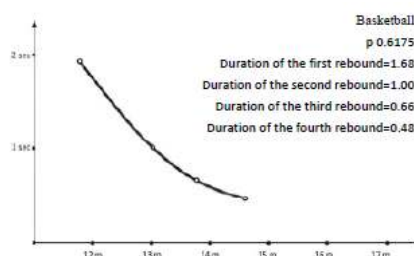
Diagram 6. Duration of rebound for p1

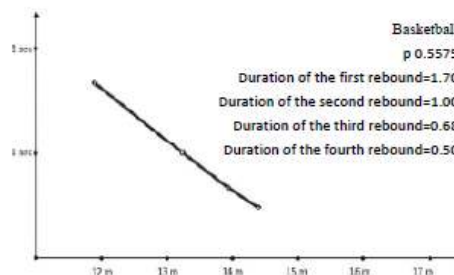---
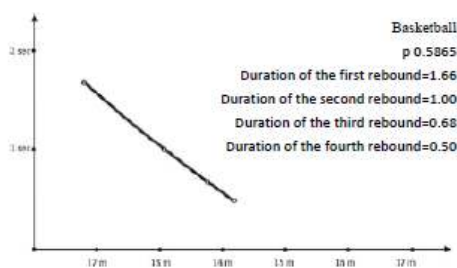
Diagram 7. Duration of rebound p2
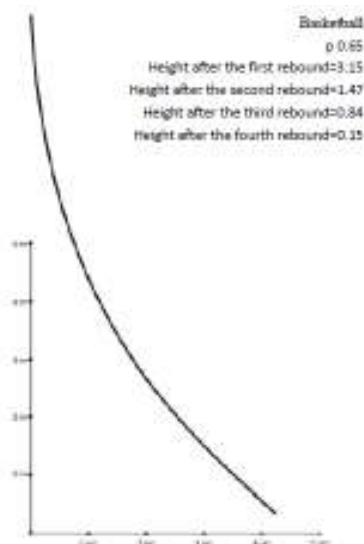

Diagram 8. Duration of rebound p3
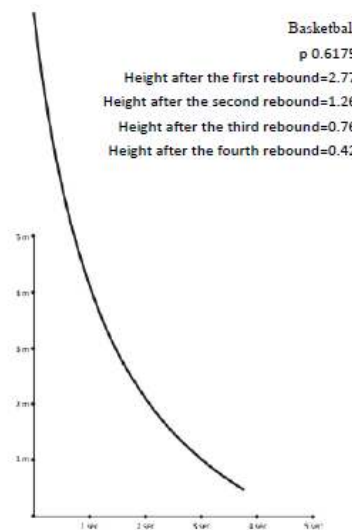

Diagram 9. Height of rebound for p

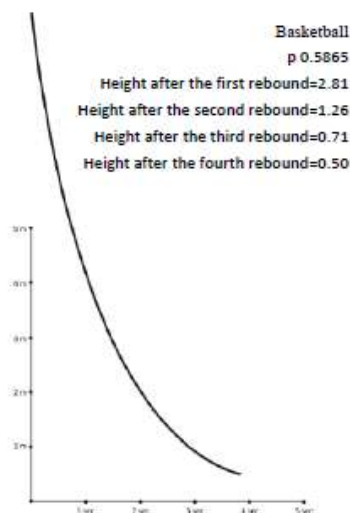
Diagram 10. Height of rebound for p1
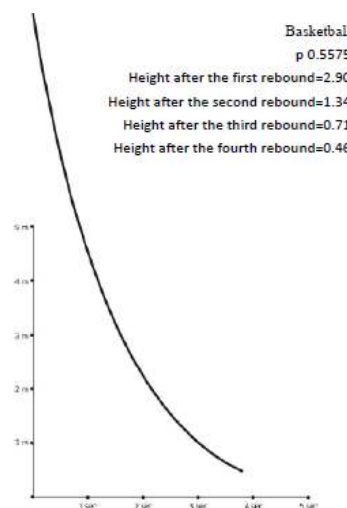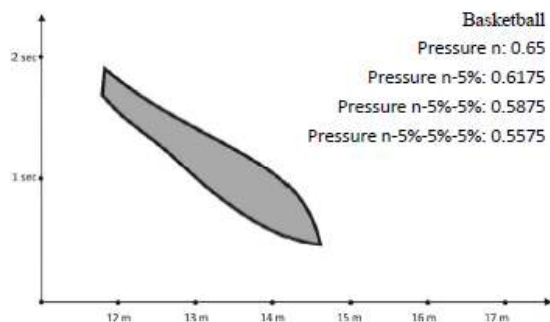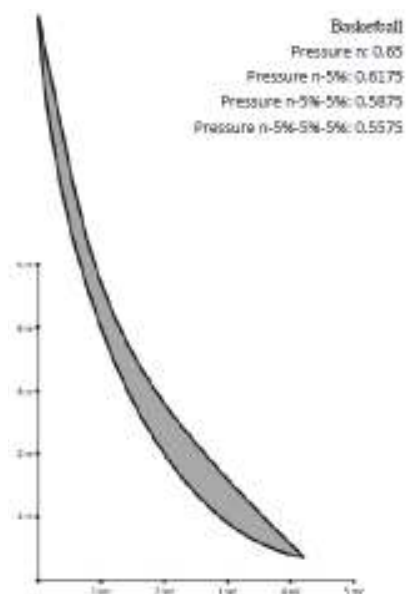

Diagram 11. Height of rebound for p2

Diagram 12. Height of rebound for p3

At the third phase it was shown the contours of diagrams of time intervals and culminating points for basketball, comparing to the tested pressures summary:

Basketball
Pressure n: 0.65
Pressure n-5%: 0.6175
Pressure n-5%-5%: 0.5875
Pressure n-5%-5%-5%: 0.5575

The contours 1. The time intervals summary

Basketball
Pressure n: 0.65
Pressure n-5%: 0.6175
Pressure n-5%-5%: 0.5875
Pressure n-5%-5%-5%: 0.5575

The contours 2. The culmination points summary

At the fourth phase were shown indexes of total duration and distance taken for basketball for four rebounds and four values of inner pressure (Table 4.), as well as associated diagrams 13, 14, 15 and 16 for each value of inner pressure separately:

Table 4. Indexes of total duration and distance taken

	Distance (m)				Duration (s)				Index=path/time			
	p	p1	p2	p3	p	p1	p2	p3	p	p1	p2	p3
After first rebound	12.15	11.77	11.81	11.90	1.72	1.68	1.66	1.70	7.064	7.006	7.114	7.000
After second rebound	13.62	13.03	13.07	13.24	2.92	2.68	2.66	2.70	4.66	4.860	4.914	4.904
After third rebound	14.46	13.79	13.78	13.95	3.66	3.34	3.34	3.38	3.95	4.009	4.129	4.127
After fourth rebound	14.61	14.61	14.21	14.41	4.22	3.82	3.84	3.88	3.46	3.820	3.589	3.714

Thinner line: total time duration (t)
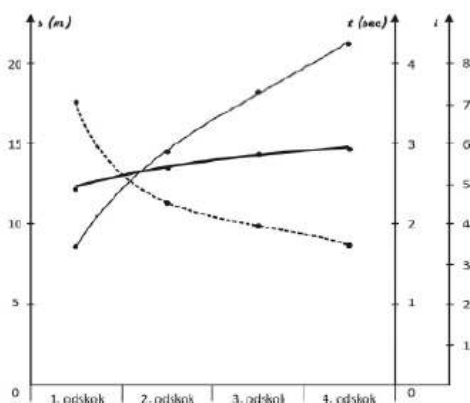Thick line: Total distance traveled (s)
Dashed line: index = s/t

Diagram 13. Total duration and distance for p

Thinner line: total time duration (t)
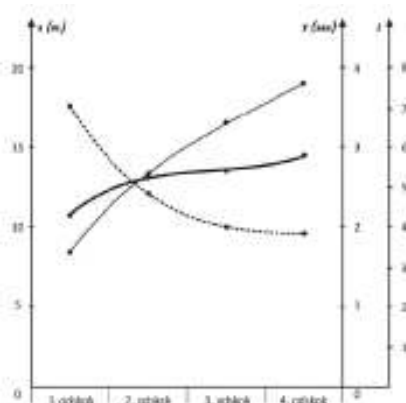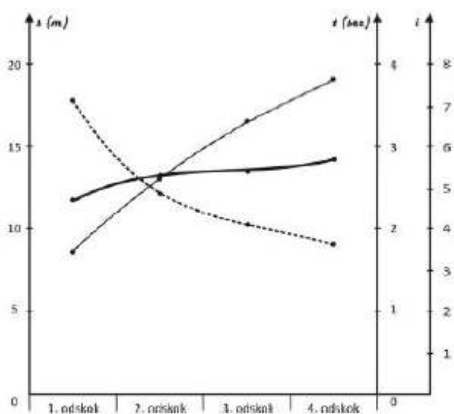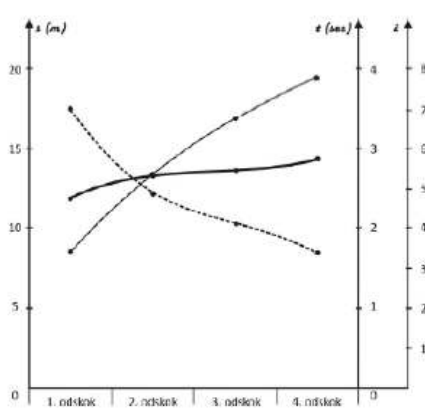Thick line: Total distance traveled (s)
Dashed line: index = s/t

Diagram 14. Total duration and distance for p1

Thinner line: total time duration (t)
Thick line: Total distance traveled (s)
Dashed line: index = s/t

Thinner line: total time duration (t)
Thick line: Total distance
Dashed line: index = s/t

Diagram 15. Total duration and distance for p2   Diagram 16. Total duration and distance for p3

At the fifth phase calculated are the repulsion coefficients for basketball, for each pressure, for each duration and each height reached (Table 5.).

Table 5. The repulsion coefficient

Pressure	After first rebound	After second rebound	After third rebound	After fourth rebound	**The average values**
p (0.65)	0.59	0.68	0.76	0.77	**0.77**
p1 (0.6175)	0.55	0.67	0.78	0.76	**0.69**
p2 (0.5865)	0.56	0.69	0.75	0.79	**0.70**
p3 (0.5575)	0.57	0.68	0.73	0.80	**0.70**

In the event of an impact of the falling ball with a solid surface, the force of the collision depends on the mass of the body in motion and acceleration that has a falling body at the moment of collision (Bjelica, 2014). Collision of elastic bodies takes place in two stages. In the first stage the substance of the collisional bodies is compressed, and this phase is called the period of compaction or compression. Due to elastic properties of substances in an impact, after the compression the second stage of a collision takes place, which is called the period of return to the previous state or restitution. Basketball, no matter how many times after its release moved vertically in free fall, it had no vertical rebound out of four successive bouncing. To be able to determine the rules of repulsions with basketball, it is necessary to determine two sizes. Spatial, i.e. the height of culmination center of gravity of each ball rebound on one hand, and the temporal, i.e. the moment of a rebound, on the other hand.

Conclusions

Looking at the sum of ball paths from the time of release to the culmination point of the fourth rebound as well as the duration of the bouncing ball from the start of the free fall until culmination point of fourth rebound, one can conclude that the distance crossed and the total duration of four successive bouncing mostly dependent on inner pressure. Inflated basketball, with the compressed air pressure greater than atmospheric, when the pressure decreases, it less bounces from the ground even though nothing in its structure has changed. The rebound of the ball is a consequence of the aspirations of compressed air, that in the period of restitution "correct" the deformed part of the ball, which was created by compression. When the air pressure in a ball is higher, the bigger is the compression, and the bigger compression, the greater will be the restitution i.e. the harder rebound from the ground.

The heights of culmination points of a basketball with all four rebounds, of which almost all were taken into account when concluding, are the metric values, which in this experiment at least unreliable. The degree of deviation from the ideal value is almost negligible and based on the obtained height values of culmination points can be reliably concluded.

After calculating the basketball repulsions coefficient, for every air pressure and every rebound it was found that the repulsions coefficient is around 0.7.

In this study, the initial speed of a basketball was unchanged and only inner pressures were changed. It was determined how much the height of the rebound is reduced and the duration of the rebound, respectively, depending on the reduction of inner pressure.

Overall, it can be concluded that the initial speed of the ball can be increased by increasing the inner pressure in the ball.

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