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DOES THE MODIFICATION OF BALL MASS INFLUENCE THE TYPES OF ATTEMPTED AND SUCCESSFUL SHOTS IN YOUTH BASKETBALL?

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ABSTRACT
Purpose. This study aimed at determining: (a) whether the effect of modifying ball mass allowed youth basketball players to attempt a greater number of lay-ups and hook shots during real games, and (b) whether the modification affected successful shots. **Methods.** Fifty-four boys from six basketball teams, aged between 10–11 years, participated in the study. The independent variable was ball mass and the dependent variable was the attempted and successful type of shots (set and jump shot, lay-ups, and hook shot). We established three situations in which four games were played with each of the following balls: (a) a regulation ball, (b) a ball of smaller mass (440 g), and (c) a ball of greater mass (540 g). Four observers were trained (intra- and inter-observer reliability > 0.96). Four observers recorded the data utilizing a systematized register from observation of the game videos. **Results.** A higher percentage of lay-ups were attempted with the 440-g ball in comparison with the regulation ball ($U = 227906$, $p = 0.01$, $ES = 0.152$) and with the 540-g ball ($U = 218614$, $p = 0.01$, $ES = 0.160$). A higher percentage of lay-ups were successful with the 440-g ball in comparison to the 540-g ball ($U = 223080$, $p = 0.02$, $ES = 0.210$). **Conclusions.** Only attempted lay-ups increased with the 440-g ball in comparison to the regulation ball, but the percentage of the rest of kinds of attempted shots and successful shots were similar when comparing the modified balls to the regulation ball.

Key words: children, rule modification, game analysis, team sport, teaching sport

Introduction

Shooting ability is very important in youth basketball for three reasons: (a) it is the technique that directly leads to scoring points, (b) it is the favorite technique of young basketball players [1], and (c) it is one of the aspects of basketball that is the most fun for children and provides them with the most satisfaction [2]. In the game of basketball, young basketball players need to use different types of shots in order to adjust their strategy to in-game situations. The problem is that most shots are quite standard in nature (i.e., the set-shot and jump-shot) in youth basketball [3–5]. Coaches and teachers need to constantly develop strategies and think up ways to solve the problem of efficient scoring through shooting.

Motor praxeology has conceptualized each sport as a motor system [6] with its own internal logic, which are the relationship dynamics between players and the structural elements of the sport as defined by a set of rules. The rules determine four types of participant relationships that cause game action to emerge: (a) with other participants, (b) within the game space, (c) with the manipulated equipment, and (d) the way in which players should adjust to game time. Consequently, each motor system has its own internal logic that causes players to carry out certain game actions in order to play the game. If any rule is changed, no matter how inconsequential, such as what kind of ball is used in the game, the game actions themselves may change.

Children normally lack the strength and physical characteristics required to efficiently perform in shooting situations [7–10]. For example, several studies that analyzed the effects of ball dimension on shooting indicated that a dimensionally smaller ball allowed for better shot technique [9] or did not impair it [10], suited children's preferences [9], and increased shot effectiveness [8, 9] or did not impair it [7, 10]. The above studies that utilized shooting test procedures found that changes in ball mass may improve shot performance and other ball handling skills. However, little attention has been given to the effect of modifying ball mass on shots performed during real games in youth basketball.

Piñar [5] analyzed the effect of introducing various rule modifications on the types of shots, among other variables, used in basketball in order to study the variability of this behavior. Piñar modified several rules (court size, the free-throw line, the three-point line, game duration, and the number of players) and found no differences in the lay-ups performed by each player (11.7% vs. 11.2%), but differences were found for standard and hook shots (12.3% vs. 15.8%) after introducing the modified variables. Arias et al. compared the effects of two shapes of the three-point line, among other variables, on the types of shots thrown. The results showed an increase in standard (35% vs. 40.5%) and hook shots (0.2% vs. 1%) when the three-point line was outlined by the free-throw lane [3].

The standard shot (e.g., the set-shot and jump shot) is the most frequently used type of shot in basketball

[3, 5, 9] and is characterized by: (a) not requiring one to move towards the basket and (b) where the shooting hand is placed behind and slightly underneath the ball, while the non-shooting hand balances the ball from the side. On the other hand, lay-ups are the most effective way to score, as well as to be charged with a personal foul [11, 12]. This type of shot decreases energy demands, allows for more control, is less affected by aerodynamic variables, and requires less ball spin [13]. The hook shot is difficult to perform [14] because it involves a lateral placement of the body with regard to the basket and an overhead shot. However, this type of shot allows one to protect the ball and one's performance in the presence of close opponents [15].

Therefore, considering the types of shots used in basketball, the objectives of this study were to determine: (a) whether the effect of modifying ball mass allowed participants to complete a greater number of lay-ups and hook shots during gameplay, and (b) whether such a modification affected the success of these shots. The first hypothesis of this study was that a reduction in ball mass would improve game play, where each type of attempted shot would become more successful with a ball of increasingly lower mass. The second hypothesis was that each type of attempted shot would be less successful with a ball of higher mass. The rationale of these hypotheses was that the dominating use of a ball in sport makes it one of the most important pieces of equipment in team sports. It is therefore very likely that players' technical-tactical shooting pattern would also change due to the modifications made to such an important component of the game [16].

Material and methods

Fifty-four boys, all aged between 10–11 years (M = 10.63 ± 0.55), were selected from six youth basketball teams to participate in this study. All belonged to official, federated teams for 2.52 ± 0.75 years and practiced each week for a total of 5.03 ± 0.80 hours. The selection of the teams and players was deliberate, as these teams fulfilled the following inclusion criteria: (a) that the team participated in all scheduled season games, (b) that the team consisted of the same players in all the games, and (c) that the selected teams from the league competed at the highest playing level, based on the opinions of coaches, and that its players were mostly homogeneous in age, previous experience and playing level. The goal of the study was only communicated to the sports director of each team, but not to the coaches or the players so that this information would not affect the way they played. The parents of the participants and the coaches completed a consent form to participate in the study. In addition, this study was approved by the Research Ethics Committee of the University (CEI 22-540).

The different basketballs that were to be tested were based on the more extreme proposals on ball mass from research on the subject. For a ball of lower mass, we selected a mass slightly less than the 467.76 g ball proposed by Satern et al. [10], weight 440 g, 69–71 cm. For a ball of higher mass, we chose a ball with a mass in between the suggested weights of other researchers. Chase et al. [7] proposed a mass of 538.65 g, while Isaacs and Karpman [8], Regimbal et al. [9], and Satern et al. [10] proposed a ball with a mass of 552.8 g. This ball was to be 540 g, 69–71 cm.

It was decided that all of the participating teams would play in real basketball games differing only in the mass of the used basketball, whether a regulation ball (485 g, 69–71 cm), the ball of smaller mass (440 g, 69–71 cm), and the ball of greater mass (540 g, 69–71 cm). A three-day tournament was organized consisting of 12 games in which the six participating teams were randomly matched. Each day, the teams played between one and two games. The game ball for each game was also randomly chosen. Between all the teams, four games were played with each ball. Each team played a minimum of one game and a maximum of two games with each ball. The tournament was organized on a weekend one week after the team finished a competitive playing stage, with the players later continuing to compete the weekend after the tournament. They were used to participating in tournaments similar to the one organized in the present study, which were not competitive in nature.

One month before the study was to begin, the coaches were informed that they would be playing in a tournament: (a) with balls provided by the organizing committee, (b) where the games would be previously staged, (c) in which all the participants would receive a diploma, and (d) they would have to respect the inclusion criteria (stated above) as well as the requisites of inter-sessional consistency. The requirements were: (a) the players were always the same ones on each team, (b) the participants played all the games on identical courts (28 × 15 m), (c) rest interval between games was a minimum of one hour, (d) each game consisted of four 10-minute periods, (e) the participants warmed up with a ball that was similar to the game ball, (f) individual defense was compulsory, (g) the height of the baskets was 2.60 m, (h) the balls were the same in texture, color, circumference and bounce, and (i) the games followed the same game rules.

A group of six experts (three researchers specialized in basketball and three coaches with experience coaching 9–11 year-old basketball players) delimited and defined the variables and their categories. The variable was the type of shot. The experts defined it as the way in which a player shoots. They studied the presence or absence of motion (traveling), arm movements, hand technique and shooting performance. As a result, the following categories of shots were chosen: (a) standard shot attempts and successful standard shots, (b) lay-up attempts and successful lay-ups, and (c) hook shot attempts and successful hook shots. The categories were

exhaustive and mutually exclusive [17]. The categories were coded using a numeric system to facilitate their register. Four observers were trained in the types of shoots that were to be registered until they accumulated a minimum of 20 hours of experience. Intra- and inter-observer reliability was later calculated by use of Cohen's kappa coefficient; inter-observer reliability reached values between 0.96 and 1 and intra-observer reliability was 1.

In accordance with Isaacs and Karpman [8], as well as with basketball regulations, the properties of the ball that were controlled were: (a) mass, (b) circumference, and (c) bounce height. Three collaborators monitored this half an hour before and after each game. They followed a protocol that was adapted by Crisco et al. [18]. This consisted of taking three measurements of each property and calculating the mean. To monitor bounce, the collaborators let the ball fall from a height of 1.80 m (measured at the bottom of the ball) and measured the height the ball reached after bouncing (at the top of the ball). The measurements were taken by recording the height and extrapolating them to the calibration mark by use of a video camera (Everio Full HD-GZ-HD7, JVC, Japan) connected to a computer (Acer Aspire 3630, Acer Inc., Taiwan). The image was then analyzed by video processing software (Virtual Dub 1.6.15), where measurements with a horizontal component were eliminated.

Two assistants recorded the games with a video camera (Everio Full HD-GZ-HD7, JVC, Japan). The camera was located transversally to the basketball court on the opposite side from the scoring table. It was placed on a tripod which could be rotated if necessary five meters off the ground, two meters from the sideline and aimed at the center of the court in order to record the entire game. As a general rule for recording, the camera was to always film the player with the ball, the court and the basket, in addition to the rest of the players. A group of four observers analyzed the data utilizing a systematized register developed for the examination of the game videos [17].

The register technique used in the study was to code the examined variables on the registry instrument [17], with the main unit of analysis being each attack phase (i.e., the percentage of each type of shot related to the number of attack phases with each ball). In order to increase observation reliability, the observers used a protocol of observing each attack phase twice at real speed. If necessary, the observers examined each attack phase at a speed of 25 frames per second. The observers registered the numeric code that corresponded to each category, with each observer observing and registering three games. The total sample size consisted of 2,100 attack phases from the 12 games, of which 736 corresponded to the four games played with the regulation ball (485 g), 660 for the four games played with the ball of smaller mass (440 g), and 704 for the four games played with the ball of greater mass (540 g).

Statistical analysis of the data was performed with SPSS v. 17.0 for Windows (SPSS, Inc., USA). We conducted descriptive analyses to measure the frequency and percentage of the type of shots taken and how successful they were. We assessed the normality of the data by the Kolmogorov-Smirnov test, which indicated that the data were non-parametric. The Kruskal-Wallis' H test was used to assess in which categories there were significant differences and post-hoc comparisons were performed with the Mann-Whitney U test to determine in which balls did these differences occur. Statistical significance was set at $p \leq 0.05$. The effect sizes (ES) for significant differences in the type of shot among different ball masses were also determined.

Results

Table 1 shows statistically significant differences for the attempted, $\chi^2(2, N = 2{,}100) = 8.448$, $p \leq 0.01$, and successful lay-ups, $\chi^2(2, N = 2{,}100) = 5.724$, $p \leq 0.05$. A higher percentage of lay-ups were attempted with the 440-g ball in comparison to the regulation ball ($U = 227906$, $p \leq 0.01$, $ES = 0.152$) and to the 540-g ball ($U = 218614$, $p \leq 0.01$, $ES = 0.160$). A higher percentage of lay-ups were successful with the 440-g ball in comparison to the 540-g ball ($U = 223080$, $p \leq 0.05$, $ES = 0.210$). Although there were statistically significant differences for the lay-ups, but not for the standard and hook shots, the differences were low in practical terms.

Discussion

The objectives of this study were to determine: (a) whether the effect of modifying ball mass allowed the study participants to attempt a greater number of lay-ups and hook shots, during real gameplay, and (b) whether this modification affected successful shots. The results do not completely confirm our original

Table 1. Frequencies, percentages, and significant differences of the means of the compared variables

Type of shot	Type of ball					
	440 g		Regulation		540 g	
	N	%	*N*	%	*N*	%
Standard attempt	284	43.1	310	42.1	296	42
Successful standard	126	19.1	105	14.9	107	14.5
Lay-up attempt	203*	30.8	181	24.6	175	24.9
Successful lay-up	90**	13.6	79	10.7	68	9.7
Hook attempt	9	1.4	9	1.2	5	0.7
Successful hook	2	0.3	1	0.1	2	0.3

* signifies the comparison of the 440-g ball to the regulation ball and to the 540-g ball, $p \leq 0.01$

** signifies the comparison of the 440-g ball to the 540-g ball, $p \leq 0.05$

hypotheses. The amount of attempted lay-ups increased with the 440-g ball in comparison to both the regulation ball and the 540-g ball. The amount of successful lay-ups increased with the 440-g ball in comparison to the 540-g ball. Neither of the types of attempted and successful shots decreased with the 540-g ball in comparison to the regulation ball. There was a similar percentage of both attempted and successful standard and hook shots with all three balls. In practical terms, the differences were non-significant according to the results of the effect size. Despite the fact that the ball is one of the most important pieces of equipment that stands as the defining characteristic of most team sports, the effect of its modification in the case of basketball was subservient to the players' physical characteristics and personal interpretation [16].

After analyzing 431 basketball shots taken by children under 12 years of age, Ibáñez et al. [14] found that 27.5% of attempted shots were lay-ups and 58.7% were standard shots. Arias et al. [3] showed that 21.3% of attempted shots were lay-ups. In the present study with the 440-g ball, the percentage of attempted lay-ups was higher while the percentage of attempted standard shots was similar. Along with the rest of the analyzed literature, this reaffirms that the 440-g ball allows for a higher percentage of lay-ups. This variation was positive as the lay-up is one of the least frequent types of shots and should be actively promoted in youth basketball [1, 14, 15].

According to Wissel [15], the reason that the number of attempted lay-ups can increase during a game is that more situations arise in which there are no opponents to hinder progress towards the basket. When compared to the way they perform with the other balls, this means that a game with a 440-g ball could facilitate children's spatial advantages over their opponent, which would allow them to shoot with a lay-up. Research has found that children direct their attention towards the interpretational aspects of the game when their physical conditions are suitable or, inversely, when the game conditions are adapted to them [19]. A reduction of ball mass may have allowed the studied basketball players to focus more on aspects about the interpretation of the game instead of focusing on aspects related solely to handling the basketball. This result seems to be in accordance with studies consulted on facilitating ball handling by reducing its mass [20, 21].

Neither the amount of attempted nor successful lay-ups decreased with the 540-g ball in comparison to the regulation ball. According to the reasoning stated above, the attempted and successful lay-ups should have both decreased when the participants played with the heavier ball in comparison to them playing with the regulation ball. However, this did not occur, as other studies have found that only an increase in ball circumference can impair the quality of the players' handling [20, 22].

In this study, we maintained the ball circumference and only modified the mass. Thus, the increase in mass of the 540-g ball in regard to the regulation ball did not particularly hinder the participants from generating more advantageous situations over their opponents.

The amount of attempted and successful standard and hook shots were similar with all three balls. These results may be related to three arguments. First, these shots are difficult to perform [14]. The standard shot demands more leg strength and better coordination [15]. Theoretically, this kind of shot increases the chance of success because it allows for a higher height of ball release [23–25]. However, it is usually the least successful shot due to the conditions basketball players play in [11]. The difficulty of the hook shot resides in the required lateral position in regard to the basket and in the required overhead shot [14]. The hook shot is recommended for throws from very close positions and with nearby opponents as it allows one to protect the ball [15]. Such a shot requires a high level of skill in these situations with numerous opponents aggressively defending their basket. Second, the standard shot is generally used more frequently and the hook shot is used more rarely [5, 9, 14, 26]. Third, and due to the above stated reasons, the players' shooting patterns with regard to the predominant and non-predominant shots used in the game seems to be so well established that it was not affected by a short-term modification in ball mass.

The modification of ball mass did not produce a critical fluctuation strong enough to cause behavior change. That is, ball mass was not a sufficiently large enough stimulus to cause the number of standard and hook shots to change. However, just because the hook shot is not used very frequently does not mean that it is not important and should not be practiced [1, 5, 9, 15]. These results reveal the need for more research in looking for other modifications in basketball that could lead to an increase in hook shots.

Conclusion

The present study provides evidence about the effect of modifying ball mass on variables exhibited during real gameplay in youth basketball. The results show that only the amount of attempted lay-ups increased with the 440-g ball in comparison to the regulation ball. The percentage of the rest of the types of attempted and successful shots were similar when comparing both the modified balls to the regulation ball. Nonetheless, youth basketball should promote lay-ups and hook shots so that adolescent players can practice the different kinds of shots necessary to successfully compete at higher levels. Modifications that lead to an improvement of these aspects of the game are very important in such a complex sport. In this study, a ball of lower mass led to an increase of attempted lay-ups. However, this ball did not increase the number of attempted or successful hook shots. This result reveals the need to study other modifications that could improve youth gameplay.

This study has several limitations: (a) only boys were studied, (b) anthropometric characteristics, biological age, strength, heart rate, perceived exertion, and skill level were not controlled, (c) nutrition characteristics and hydration level were not tested, and (d) a description of game situations in which the particular shots were used was not made. These conditions may limit a more simplified explanation of the results and restrict them only to participants with similar characteristics to those in this study. Moreover, these results should be analyzed with precaution due to the data on effect size. All of these shortcomings should be taken into consideration in future studies.

The results exemplify how modifying a relationship between players and the equipment they use produces changes in game actions. This supports the need to further analyze what changes in gameplay occur after a modification is introduced and how these changes interact with a given component of the motor system. The conceptualization of team sports as motor systems allows us to consider and facilitate such analysis.

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