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Original Article

Positive effect of a scaled ball on the free throw technique in under-12 basketball

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Abstract
Problem Statement: Under-12 basketball is one of those youth sports that children can practice before going on to play basketball. However, the lack of shooting success is a common problem in under-12 basketball, which minimises their expectation to be physically active in the future. **Purpose:** The aim was to explore whether the (in general and successful) free throw technique was similar to the ideal technique proposed by the literature when using a lighter ball (440 g) in under-12 basketball. Participants were 45 players from five male teams. **Method:** Players were filmed performing a free throw test with the regular ball (490 g, 69-71 cm) and a lighter ball (440 g, 69-71 cm). They were tested midway through the season in the month of March. Each day, the test was performed by one team, so all the teams were tested in the two-week period. They performed 270 free throws with each ball, which were observed and later analysed as a group. The criteria analysed of each free throw were differentiated according to prior to ball release and at ball release. **Results:** The lighter ball allowed free throws ($p < .05$) with high style prior to ball release, supporting hand lateral and static, upper line, shooting hand orientated toward the basket, shooting arm very close to the vertical, and shooting wrist fully bent at ball release. In addition, this ball allowed successful free throws ($p < .05$) without jumping prior to ball release, in which the ball was released at the point of maximum height, upper line, and shooting wrist fully bent at ball release. The mean frequency of patterns was higher with the lighter ball at ball release. **Conclusions:** The lighter ball allowed a free throw technique similar to the ideal technique and a more regular free throw technique at ball release. This suggests that there was scope for improvement in scaling the regular ball because diminishing the ball mass could promote the execution of the free throw in conditions better tailored to the players.
Key Words: **Youth basketball, learning contexts, sport pedagogy, scaled equipment, physical education**.

Introduction

Participation in organized youth sports predicts that children can remain physically active in adulthood as long as the context allows them to experiment positive sport experiences (Miller, & Siegel, 2017; Niemistö et al., 2019). In fact, studies highlighted the importance of success in sports during childhood in order to develop a long-term active lifestyle (e.g., Jaakkola et al., 2019; McIntyre et al., 2018). Under-12 basketball is one of those youth sports that children can practice before going on to play basketball. However, the lack of shooting success is a common problem in under-12 basketball, which minimises their expectation to be physically active in the future (Arias, 2012a).

Scaling the equipment in youth sports leads children to play and enjoy playing according to their possibilities, to develop correct technical patterns and, as a consequence, to promote success in their game actions (Buszard et al., 2020; Limpens et al., 2018). Regarding the scaling of the ball in under-12 basketball, Satern et al. (1989) showed that a lighter ball (490 g) had no effect on any of the free throw technical parameters measured due to the ball not being light enough for children to cause changes. Similarly, also Chase et al. (1994) found no improvements in free throw success with a lighter ball (530 g), but they did find greater self-efficacy before the free throws with this ball. Kinnunen, et al. (2001) concluded that the ratio between grip strength and ball size may be a key factor to obtain success in the free throw using a lighter ball (480 g). Regimbal et al. (1992) observed an improvement in free throw technique when instructions were given and a lighter ball used (470 g). Subsequently, considering Satern et al. (1989) and Chase et al.'s (1994) previous suggestions, the Arias research group analyzed the use of an even lighter ball (440 g) during official competitions, finding higher accuracy and success in field shots (Arias, 2012a), free throws (Arias, 2012b) and an increase in the free throw shot attempts, the 2-point field goal attempts, successful free throws, and successful 3-point field goals (Arias-Estero et al., 2012).

Regarding the free throw technique, Díaz-Aroca and Arias-Estero (2020a) found that the majority of U12 players did not execute the free throw correctly. In relation, U12 players often make baskets by executing a similar technique to that of missed shots (Díaz-Aroca & Arias-Estero, 2020b). Recently, Díaz-Aroca and Arias-Estero (2022) observed that U12 players executed an unregulated technique in the free throw with a ball of 485g.

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Data from the literature suggest that release height, velocity, and angle are the main factors related to a successful free throw (e.g., Okazaki et al., 2015). Furthermore, researchers identified prior to ball release and at ball release as the two key moments of free throw study (e.g., Okubo & Hubbard, 2016). Echoing these biomechanical variables, several basketball manuals recommended the ideal free throw technique (e.g., Krause & Nelson, 2019). Prior to ball release, the free throw should be executed without jumping, high style, shooting with one hand and using the other as a supporting hand, static and lateral, feet pointed towards the basket, with same-side foot of the shooting hand placed forward. At ball release, the shooting hand should be oriented towards the basket, elbow extended and arm very close to the vertical, upper line, wrist bent, and the ball should release at the point of maximum height of the centre of mass with no shoulder rotation, and no horizontal displacement of the centre of mass.

In short, the use of a lighter ball seems to have improved free throw accuracy and success, but there is no study analysing the effect of such a ball on the free throw technique using a court-applied test. The aim of the present study was to explore whether the free throw technique and successful free throw technique were similar to the ideal technique proposed by the literature, using a lighter ball (440 g) in comparison to the regular ball (490 g), in under-12 basketball. The first hypothesis was that the lighter ball would allow the participants to execute the free throws and successful free throws using a technique similar to that proposed by the literature. The second hypothesis was that the free throw technique and successful free throw technique would be more regular with the lighter ball in comparison to the regular ball.

Material & methods

Participants

The participants were 45 players (M_{age} = 10.86 years, *SD* = .51 years, age range = 9–11 years), from five male under-12 formal basketball teams that played regionally. Participants trained an average of 3.81 (*SD* = .59) days, for an average of 4.31 hr per week (*SD* = .71) and they played competitive matches at least once a week. These teams participated for three reasons. First, they accepted: (a) participating in all scheduled tests, and (b) being recorded during each test. Second, they competed at the top regional level. Third, they had homogeneous features related to previous basketball experience (*M* = 3.56, *SD* = .25 years, $p > .05$), strength level (*M* = 22.10, *SD* = 1.06 Nw, $p > .05$), maturity offset (*M* = -1.36, *SD* = .38, $p > .05$), height (*M* = 1.44, *SD* = .16 m, $p > .05$), and weight (*M* = 40.7, *SD* = 8.75 Kg, $p > .05$). Participants' parents completed informed consent forms, and participants also provided their assent. The University's Research Ethics Committee approved the study and it was performed according to the Helsinki Declaration.

Design

Players were filmed performing a free throw test with the regular ball (490 g, 69-71 cm) and a lighter ball (440 g, 69-71 cm). They were tested midway through the season in the month of March. Each day, the test was performed by one team, so all the teams were tested in the two-week period (Tuesday, Wednesday, Thursday). They performed 270 free throws with each ball, which were observed and later analysed as a group. The criteria analysed of each free throw were differentiated according to prior to ball release and at ball release (Díaz-Aroca & Arias-Estero, 2022). These criteria were determined deductively (including all criteria and categories obtained after a thorough theoretical review of the technique of free throw) and inductively (including all the criteria and category possibilities after observing 2852 free throws of the studied population). In addition, the success of each free throw, understood as a result of scoring or not scoring a basket, was recorded.

Procedure

Researchers tested each team individually during a training session from 16:30 to 18:30 hours, at a similar environmental temperature (22.9–23.1 ºC) and in the same experimental setup: (a) a free throw 4 m from the basket, (b) located 2.60 m high, and (c) with a regular ball of 490 g and a lighter ball of 440 g. Each team was assigned to a test day by simple randomization. Two cameras were used (Everio Full HD-GZ-GX1BE, JVC, Japan), at a height of 1.30 m and 5 m from the player. One was placed sideways and parallel to the player in the free throw position, to record the player, the trajectory of the ball and the basket. The other camera was placed under the basket in order to record the player head-on, as well as the ball release trajectory. This test was previously piloted to verify that there was no influence due to the order of execution of the free throw options or the moment when participants executed the free throw. Coaches were asked not to train any differently than usual. They stated that players did not use to practice the free throw throughout their training sessions.

All the teams performed the same pre-test exercises. First, a general warm-up, consisting of joint mobility (5 minutes), stretching (5 minutes), and dribbling while running (3 minutes). Second, a task of handling the ball while dribbling (5 minutes) and another task of lay-ups (5 minutes). After the shooting task, the participants began to perform the test. The rest of the participants continued to perform dribbling tasks and alternating shots at low intensity to avoid fatigue. Participants did not practice the free throw prior to the test.

The test consisted of performing 12 free throws, 6 with each ball. Specifically, each player performed three free throw options to resemble what occurs in a real game (one, two and three free throws) with each ball (regular and lighter). The performance was done in pairs, so that one participant performed the free throws and the other passed the ball to him. By means of simple randomization, as instructed by the principal investigator, each participant shot one, two or three free throws with the regular and the lighter balls, which also were simple

randomized. After each of the previous options of free throw, the roles were exchanged until both participants performed all the free throw options with both balls. No player shot more than three free throws in a row. Once the participant had the ball, he had 5 seconds to shoot, as indicated by the regulations. Participants were asked to face free throw as they normally do in real matches. When the pair finished performing the test, another pair would start it. The order of participation of the participants was also by simple randomization. Each pair required less than 15 minutes to take the test and, in total, each team required less than 90 minutes to take the test.

The videos of the free throws were observed by three observers with more than 11 years of coaching experience in under-12 basketball and more than 950 hours of experience in observing game actions in under-12 basketball. They were trained for 15 hours for the observation of the specific criteria of this study. The reliability of observers at the end of the training was calculated (intraclass correlation coefficient > .96, and percentage of agreement > 91%).

The observers used a systematized observation to record data from the videos. This observation technique consisted of registering, in each cell of the register instrument, the category met in each criterion for each participant's free throw. The observers observed each free throw individually. Each observer observed a maximum of 60 free throws in each observation session to avoid the effect of fatigue. They started each session by re-observing all 30 free throws of the previous session to detect possible errors and then, they observed 30 new free throws. The observers viewed each free throw three times at real speed. If necessary, they observed each free throw at a speed of 25 frames/s. They observed the videos of the free throws recorded laterally and from in front of the participants. The observers required 26 hours over five weeks to observe the 540 free throws executed by the participants. The three observers observed all the free throws. Then, they discussed any disagreements until reaching an agreement.

Data analysis

First, a-priori power analysis (α = .05 [two-tailed], β = .95, large effect [.5]) indicated that a minimum of 210 samples were necessary. This minimum was met in the current study, with a total of 540 samples included in the analysis. Second, *t*-tests were used to assess possible differences between balls regarding the free throw criteria in general and the successful free throw criteria. Statistical significance was set at $p < .05$. Also, we calculated the coefficient of variation and the effect sizes using *d* (Cohen, 1988). Third, the Theme v6 EDU (Magnusson, M. S., Burgoon, J. K., & Casarrubea, 2016) software was used to perform the analysis that enabled the detection of patterns of the free throw technique in general and the successful free throw technique for each ball. This analysis allowed determining the regularities of the free throw pattern. We also checked whether the results were influenced by the randomization of: (a) free throw options' order (one, two or three), (b) participants' free throw moments (start or end of each session), (c) balls' order (regular or lighter), and (d) the different teams. This checking was done in each of the above-mentioned analyses, so that all the former tests were used. All the previous analyses were carried out differentiating the criteria prior to ball release and at ball release.

Results

Of the 270 free throws performed with each ball, 96 were successful when the participants shot with the regular ball and 105 when they shot with the lighter ball. Prior to ball release (Table 1), the results showed a statistically significant increase in the number of free throws executed with high style, t = -2.11, p = .035, with the lighter ball in comparison to the regular ball. At ball release (Table 2), the results showed a statistically significant increase in the number of free throws executed with the supporting hand lateral and static, t = -2.25, p = .025, upper line, t = -1.98, p = .048, shooting hand orientated toward the basket, t = -2.57, p = .012, shooting arm very close to the vertical, t = -2.08, p = .038, and shooting wrist fully bent, t = -2.37, p = .018, with the lighter ball in comparison to the regular ball.

Table 1. Means, standard deviations and significant differences of the free throw criteria comparing both balls prior to ball release

Criteria	Regular ball			Lighter ball			*t*	*p*	*d*
	M	*SD*	*CV*	*M*	*SD*	*CV*			
Without jumping shot	.11	.31	2.81	.15	.35	2.33	-1.14	.253	.14
Jumping shot	.89	.31	.34	.85	.35	.41	1.14	.253	.14
High shooting style	.15	.35	2.33	.22	.41	1.86	-2.11	.035*	.21
Low shooting style	.85	.35	.41	.78	.41	.52	2.11	.035*	.21
One shooting hand	.89	.31	.34	.89	.31	.34	.00	1.000	.00
Both shooting hands	.11	.31	2.81	.11	.31	2.81	.00	1.000	.00
Shooting hand below the ball	.87	.33	.37	.89	.31	.34	-.66	.509	.07
Shooting hand on the side of ball	.02	.13	6.50	.02	.13	6.50	.00	1.000	.00
Shooting hand below and on the side of ball	.04	.18	4.50	.04	.18	4.50	.00	1.000	.00
Both shooting hands behind the ball	.02	.13	6.50	.02	.13	6.50	.00	1.000	.00
Both shooting hands on the side of ball	.06	.22	3.66	.04	.18	4.50	1.02	.307	.11
No support hand	.11	.31	2.81	.11	.31	2.81	.00	1.000	.00

Support hand on the side of ball	.83	.37	.44	.81	.38	.46	.56	.573	.06
Support hand below the ball	.00	.00	.00	.02	.13	6.50	-1.25	.089	.35
Support hand behind the ball	.02	.13	6.50	.02	.13	6.50	.00	1.000	.00
Support hand above the ball	.04	.18	4.50	.04	.18	4.50	.00	1.000	.00
Shooting elbow very bent	.29	.45	1.55	.29	.45	1.55	.00	1.000	.00
Shooting elbow medium bent	.71	.45	.63	.71	.45	.63	.00	1.000	.00
Both feet point towards the basket	.85	.36	.42	.85	.36	.42	.00	1.000	.00
Only same-side foot as the shooting hand points toward the basket	.10	.29	2.90	.08	.26	3.25	.76	.446	.08
No foot points toward basket	.06	.22	3.66	.07	.26	3.71	-.87	.383	.04
Feet placed at same distance	.68	.46	.67	.60	.49	.81	1.06	.059	.19
Same-side foot of shooting hand placed forward	.32	.46	1.43	.40	.49	1.22	-1.88	.060	.19
Opposite foot of shooting hand placed forward	.00	.00	.00	.01	.08	8.00	-1.41	.157	.28

*$p < .05$.

Table 2. Means, standard deviations and significant differences of the free throw criteria comparing both balls at ball release

Criteria	Regular ball			Lighter ball			*t*	*p*	*d*
	M	*SD*	*CV*	*M*	*SD*	*CV*			
Ball released at the point of maximum height of the centre of mass	.48	.50	1.04	.48	.50	1.04	.00	1.000	.00
Ball released before the point of maximum height of the centre of mass	.52	.50	.92	.52	.50	.92	.00	1.000	.00
Support hand lateral and static	.74	.43	.58	.78	.41	.52	-2.25	.025*	.35
Support hand moves down	.14	.34	2.42	.13	.33	2.53	.37	.706	.03
Support hand separates laterally	.02	.13	6.50	.00	.00	.00	.90	.365	.11
No support hand	.09	.29	3.22	.09	.29	3.22	.00	1.000	.00
Upper line shooting hand	.87	.33	.37	.92	.26	.28	-1.98	.048*	.19
Under line shooting hand	.13	.33	2.53	.08	.26	3.25	1.98	.048*	.19
Shooting hand orientated towards the basket	.89	.31	.34	.95	.22	.23	-2.57	.012*	.26
Shooting hand orientated inward	.11	.31	2.81	.05	.22	4.40	2.57	.012*	.26
Shooting elbow fully extended	.92	.27	.29	.88	.32	.36	1.43	.152	.15
Shooting elbow not very extended	.07	.26	3.71	.12	.32	2.66	-1.75	.080	.19
Shooting elbow very bent	.01	.08	8.00	.00	.00	.00	1.41	.157	.28
Shooting arm very close to the vertical	.13	.34	2.61	.20	.40	2.00	-2.08	.038*	.21
Shooting arm close to the vertical	.75	.43	.57	.71	.45	.63	.97	.331	.10
Shooting arm not close to the vertical	.11	.31	2.81	.09	.28	3.11	1.14	.252	.07
Shooting wrist fully bent	.84	.36	.42	.91	.28	0.30	-2.37	.018*	.25
Shooting wrist incompletely bent	.16	.36	2.25	.09	.28	3.11	2.37	.018*	.25
Long forward horizontal displacement of centre of mass	.14	.34	2.42	.17	.37	2.17	-.83	.405	.09
Moderate forward horizontal displacement of centre of mass	.60	.49	.81	.55	.49	.89	1.21	.223	.11
Long backward horizontal displacement of centre of mass	.00	.00	.00	.02	.13	6.50	-1.64	.101	.35
Moderate backward horizontal displacement of centre of mass	.05	.22	4.40	.06	.27	4.50	-.37	.708	.04
No displacement of centre of mass	.20	.40	2.00	.20	.40	2.00	-.10	.915	.00
No shoulder rotation	.83	.38	.45	.81	.38	.46	.33	.737	.06
Shoulder rotation to the right	.03	.18	6.00	.04	.18	4.50	-.23	.816	.06
Shoulder rotation to the left	.14	.34	2.42	.15	.35	2.33	-.24	.807	.03

*$p < .05$.

Focusing on the successful free throws, prior to ball release (Table 3), the results showed a statistically significant increase in the number of free throws without jumping, $t = -2.78$, $p = .006$, with the lighter ball in comparison to the regular ball. At ball release (Table 4), the results showed a statistically significant increase in the number of free throws in which the ball was released at the point of maximum height of the centre of mass, $t = -235$, $p = .019$, upper line, $t = -2.51$, $p = .013$, and shooting wrist fully bent, $t = -2.42$, $p = .016$, with the lighter ball in comparison to the regular ball.

The coefficient of variation was lower in all the criteria improved when participants used the lighter ball, both in the free throws in general and the successful free throws, suggesting that the technique improved homogeneously (Tables 2, 3, 4 and 5).

Table 3. Means, standard deviations and significant differences of the successful free throw criteria comparing both balls prior to ball release

Criteria	Regular ball			Lighter ball			*t*	*p*	*d*
	M	*SD*	*CV*	*M*	*SD*	*CV*			
Prior to ball release									
Without jumping shot	.10	.30	3.00	.25	.43	1.72	-2.78	.006**	.47
Jumping shot	.90	.30	.33	.75	.43	.57	2.78	.006**	.47
High shooting style	.22	.41	1.86	.21	.41	1.95	.08	.930	.02
Low shooting style	.78	.41	.52	.79	.41	.51	-.08	.930	.02
One shooting hand	.94	.24	.25	.87	.33	.37	1.54	.124	.28
Both shooting hands	.06	.24	4.00	.13	.33	2.53	-1.54	.124	.28
Shooting hand below the ball	.92	.27	.29	.87	.33	.37	.98	.325	.19
Shooting hand on the side of ball	.02	.14	7.00	.03	.16	5.33	-.37	.710	.07
Shooting hand below and on the side of ball	.02	.14	7.00	.03	.16	5.33	-.37	.710	.07
Both shooting hands behind the ball	.00	.00	.00	.02	.13	6.50	-1.42	.158	.35
Both shooting hands on the side of ball	.04	.20	5.00	.05	.21	4.20	-.23	.817	.05
No support hand	.06	.24	4.00	.13	.33	2.53	-1.54	.124	.28
Support hand on the side of ball	.89	.32	.35	.80	.40	.50	1.73	.085	.28
Support hand behind the ball	.03	.17	5.66	.04	.19	4.75	-.28	.773	.06
Support hand above the ball	.02	.14	7.00	.04	.19	4.75	-.73	.461	.14
Shooting elbow very bent	.26	.44	1.69	.39	.49	1.25	-1.93	.054	.32
Shooting elbow medium bent	.74	.44	.59	.61	.49	.80	1.93	.054	.32
Both feet point towards the basket	.89	.32	.35	.88	.32	.36	.04	.966	.03
Only same-side foot as the shooting hand points toward the basket	.06	.24	4.00	.04	.19	4.75	.76	.448	.10
No foot points toward basket	.05	.22	4.40	.08	.26	3.25	-.72	.468	.14
Feet placed at same distance	.72	.45	.62	.61	.49	.80	1.60	.110	.27
Same-side foot of shooting hand placed forward	.28	.45	1.60	.39	.49	1.25	-1.60	.110	.27

**$p < .00$

Table 4. Means, standard deviations and significant differences of the successful free throw criteria comparing both balls at ball release

Criteria	Regular ball			Lighter ball			*t*	*p*	*d*
	M	*SD*	*CV*	*M*	*SD*	*CV*			
Ball released at the point of maximum height of the centre of mass	.42	.49	1.16	.58	.49	.84	-2.35	.019*	.37
Ball released before the point of maximum height of the centre of mass	.58	.49	.84	.42	.49	1.16	2.35	.019*	.37
Support hand lateral and static	.74	.44	.59	.78	.41	.52	-.60	.543	.10
Support hand moves down	.19	.39	2.05	.12	.32	2.66	1.38	.167	.22
Support hand separates laterally	.01	.10	10.00	.00	.00	.00	1.00	.320	.23
No support hand	.06	.24	4.00	.11	.31	2.81	-1.12	.262	.21
Upper line shooting hand	.84	.36	.42	.95	.21	.22	-2.51	.013*	.44
Under line shooting hand	.16	.36	2.25	.05	.21	4.20	2.51	.013*	.44
Shooting hand orientated towards the basket	.90	.30	.33	.92	.26	.28	-.64	.517	.08
Shooting hand orientated inward	.10	.30	3.00	.08	.26	3.25	.64	.517	.08
Shooting elbow fully extended	.93	.26	.27	.94	.23	.24	-.41	.678	.04
Shooting elbow not very extended	.07	.26	3.71	.06	.23	3.83	.41	.678	.04
Shooting arm very close to the vertical	.18	.38	2.11	.19	.39	2.05	-.30	.758	.03
Shooting arm close to the vertical	.71	.45	.63	.71	.45	.63	-.01	.995	.00
Shooting arm not close to the vertical	.11	.32	2.90	.10	.29	2.90	.40	.690	.03
Shooting wrist fully bent	.83	.37	.44	.94	.23	.24	-2.42	.016*	.42
Shooting wrist incompletely bent	.17	.37	2.17	.06	.23	3.83	2.42	.016*	.42
Long forward horizontal displacement of centre of mass	.11	.32	2.90	.13	.33	2.53	-.25	.802	.07
Moderate forward horizontal displacement of centre of mass	.67	.47	.70	.54	.50	.92	1.78	.077	.31
Long backward horizontal displacement of centre of mass	.00	.00	.00	.03	.16	5.33	-1.74	.083	.43
Moderate backward horizontal displacement of centre of mass	.01	.10	10.00	.02	.13	6.50	-.51	.605	.10
No displacement of centre of mass	.21	.40	1.90	.28	.45	1.60	-1.20	.231	.19
No shoulder rotation	.86	.34	.39	.86	.34	.39	.01	.992	.00
Shoulder rotation to the right	.01	.10	10.00	.02	.13	6.50	-.51	.605	.10
Shoulder rotation to the left	.13	.33	2.53	.12	.32	2.66	.18	.855	.03

*$p < .05$

The mean frequency of patterns was higher in the free throws in general than in the successful ones prior to ball release and at ball release using both balls (Table 5). Furthermore, the mean frequency of patterns in general and with success was higher prior to ball release than at ball release with both balls (Table 5). However, prior to ball release, the mean frequency of patterns in general free throws and successful free throws was higher with the regular ball than with the lighter ball (Table 5). On the contrary, at ball release, the mean frequency of patterns in general free throws and successful free throws was higher with the lighter ball in comparison to the regular one (Table 5). The results showed no statistical significant differences when we checked whether the data were influenced by the randomization effect of free throw options' order, participants' free throw moments, balls' order, and different teams ($p > .05$)

Table 5. Number, types and mean frequency of free throw patterns prior to ball release and at ball release, in general and with success, with both balls

Free throw moments	Regular ball			Lighter ball		
	n (types)	*n* (total)	Mean frequency	*n* (types)	*n* (total)	Mean frequency
Prior to ball release	40	270	6.75	41	270	6.58
At ball release	81	270	3.33	74	270	3.64
Prior to ball release with success	27	96	3.55	32	105	3.28
At ball release with success	44	96	2.18	39	105	2.69

Dicussion

The aim of the present study was to explore whether the free throw technique and successful free throw technique was similar to the ideal technique proposed by the literature using a lighter ball (440 g) in comparison to the regular ball (490 g), in under-12 basketball. The results ratified the first hypothesis because the lighter ball allowed the participants to execute free throws and successful free throws using a technique similar to the one proposed in the literature. However, the results did not totally ratify the second hypothesis because the free throw technique and the successful free throw technique were more regular with the lighter ball at ball release but not prior to ball release. These results suggested that the regular conditions of free throw were not appropriate for the physical characteristics of the participants (Arias-Estero et al., 2012; Garzón et al., 2014). Especially, such conditions affected the pattern at ball release, where more criteria improved with the lighter ball and the pattern was more regular than prior to ball release, and in comparison to the regular ball at ball release. Therefore, it is not that children lack the strength required to shoot the free throw, but the equipment is not scaled to their physical characteristics (Buszard et al., 2020). Consequently, the participants improved the technique, finding the optimal movement solution using the lighter ball, due to the fact that the body is biologically designed to self-organize optimal movement patterns when the ball (constraint) imposes such a need (Palmer et al., 2018). Furthermore, although the participants only achieved nine successful free throws more with the lighter ball in comparison to the regular one, according to Gómez et al. (Gómez et al., 2018) suggestion, the fact that the modified ball led to a technical improvement at an early stage could minimise the low percentages of successful free throws in late stages. Hence, although the lighter ball may have provided the participants with the opportunity to perform in a better tailored free throw condition, a greater improvement could be achieved if players practised with such a ball and with the coaches' instructions (Regimbal et al., 1992).

As in previous studies (Garzón et al., 2014), using the regular ball requires that the ball is released before the point of maximum height of the centre of mass and with a low style in order to generate higher force that allows the ball to touch the rim. However, in the present work, the lighter ball allowed the participants to perform the free throw using a high style prior to ball release and an upper line style with the shooting arm very close to the vertical at ball release (Tables 2 and 3). These three technical criteria conform a more ipsilateral shooting style that requires more strength from the shooting hand that many young players lack (Matulaitis et al., 2021; Okazaki et al., 2015). Therefore, the lighter ball could have minimised such demands. In this regard, the participants increased the number of successful free throws in which the ball was released at the point of maximum height of the centre of mass (Table 4). Increasing the angle and height of ball release leads to a decrease of release speed, and these factors are positively related to the angle of ball entry into the basket. A free throw with these characteristics is more likely to be successful (Okazaki et al., 2015).

In relation to the above biomechanical factors, the height of ball release promotes the bending of the wrist. Especially, the overhand high style demands more individual wrist strength (Okazaki et al., 2015). This could have been why, with the lighter ball, the participants increased the mean frequency of free throws in which the shooting wrist was fully bent (Table 2). Furthermore, the lighter ball also allowed a higher frequency of successful free throws in which the shooting wrist was fully bent (Table 4). This higher frequency could be explained because full wrist bending generates two effects (Okubo & Hubbard, 2016). First, it contributes to increase the ball's release velocity. Second, it allows the backspin, which tends to redirect the ball towards the centre of the basket after any left or right error with a bounce on the far rim.

According to Gómez, et al. (2017), the placement of the supporting hand lateral and static allowed the players to improve the technique, as in the present work with the lighter ball, due to an increase in shooting stability. Such

stability enables the shooting hand to properly direct the ball (Chase et al., 1994). That was why, when using the lighter ball, the participants concluded the free throw with the shooting hand orientated towards the basket, as studies recommend (Krause & Nelson, 2019). This final movement towards the basket is necessary to culminate the kinetic chain that transfers the force from the lower-body to the upper-body (Okazaki et al., 2015). Furthermore, in the present study with the lighter ball, there was an increase in the mean frequency of successful free throws performed without jumping. Similarly, Garzón, et al. (2014) also found that performing the free throw without jumping increased success because stability was greater. Movement stability and postural control are essential features for shooting accuracy (Palmer et al., 2018). However, players may shoot without stability as a strategy to capitalise on the potential energy created both by the elbow extensor muscles and pre-stretching the wrist flexors, as a requirement of using the regular ball. These strategies generate greater force and speed that can be applied to the ball at release, thereby decreasing the needed stability for a successful shot (Okazaki et al., 2015).

According to previous studies (Gómez et al., 2017; Okazaki et al., 2015), it was hypothesised that the lighter ball would allow the regularity of the free throw pattern, preventing the use of different non-regular compensatory strategies caused by the children's common lack of strength when performing a free throw in non-scaled conditions. However, the participants improved their technique in more criteria and the patterns were more regular at ball release when using the lighter ball than prior to ball release because there were more free throws performed following an incorrect technique at ball release with the regular ball. This finding was supported by two facts. First, the free throw technique in general and the successful free throw technique were more regular with both balls prior to ball release. The patterns were even more regular with the regular ball in comparison to the lighter ball prior to ball release because the players were used to playing with the former ball. As a consequence, the participants could adopt a more regular technique prior to ball release compared to what happened at ball release, in order to generate the necessary force to achieve success (Chen et al., 2018). Second, the participants could improve the technique more at ball release than prior to ball release with the lighter ball because this shooting moment is quite irregular (Sevrez & Bourdin, 2015). Furthermore, in contrast to previous studies, the results of both balls showed that the successful free throw pattern was less regular than the general free throw pattern (Przednowek et al., 2018). On the contrary, the free throw is a special component based on automatic movements, always performed in the same way at a suitable rhythm and speed (Przednowek et al., 2018). Thus, the lighter ball could contribute to automate the free throw at ball release.

To sum up, the results of the present work were opposed to those shown in previous studies (Chase et al., 1994; Satern et al., 1989). However, they were similar to those reported by Arias (2012a, b), and Regimbal et al. (1992). The different findings of the studies could be explained by the fact that the modified ball in the present work was lighter than the 490 g ball tested in Satern et al. (1989) and than the 530 g ball tested in Chase et al. (1994). Furthermore, in comparison to what was done in the former studies, in which there were no statistically significant improvements after comparing pre-existent smaller official balls, in the present study, the ball was designed on purpose with the same diameter but diminishing the mass by 50 g. In other words, although the previous studies made an effort to test the effects of a smaller ball than that used in senior basketball, there is still room for improvement in order to scale the ball to children's physical characteristics. This suggestion is supported by Torres-Unda, et al. (2015), who found that maturity was associated with better shooting performance.

Conclusions

In conclusion, the present work analysed the free throw technique by means of observable criteria which allowed information that can be directly applied by coaches. The lighter ball allowed the participants to execute free throws and successful free throws using a technique similar to the one proposed in the literature. Concretely, there was an increase in the number of free throws executed with high style, executed with the supporting hand lateral and static, upper line, shooting hand orientated toward the basket, shooting arm very close to the vertical, and shooting wrist fully bent, with the lighter ball in comparison to the regular ball. In addition, the free throw technique and the successful free throw technique were more regular with the lighter ball at ball release but not prior to ball release. This information supports the use of the scaled ball because it led to a better free throw technique and more regular. However, although the number of successful free throws was not greater in practical terms with the lighter ball, such a ball let the performance of technical criteria that occurred less with the regular ball. Consequently, the lighter ball would promote that coaches could teach the shooting using a better technique, what it is difficult to teach using the regular ball. Hence, training with the modified ball, together with the coach's instructions to promote the ideal free throw technique, could favour the development of a more correct free throw technique and an increase of the successful free throw. Nevertheless, this is a proposal that should be investigated in further studies.

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