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MONITORING BALL SPEED OF THE VOLLEYBALL SPIKE THROUGHOUT THE SEASON FOR ELITE WOMEN´S VOLLEYBALL PLAYERS

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ABSTRACT

The aim of this study was to test the viability of monitoring the evolution of the speed of the spike for women´s volleyball players throughout a season. The sample included 10 players from a volleyball club of Spain´s first division. A descriptive and correlational study of repeated measures was carried out. The variable that was studied was the speed of the ball in the standing spike test and the jump spike test. The ball speed was monitored throughout the 23 weeks of the competitive season. The tests were integrated into the team´s normal training routines. A descriptive analysis (means, standard deviation, and variability percentages) and an inferential analysis (Friedman test, linear regression, and Wilcoxon test) were done. The results show mean speeds of 71.2 ± 5.1 km/h for the jump spike and 70.7 ± 6.2 km/h for the standing spike. Increases of 2.3% for the jump spike and 0.4% for the standing spike were observed throughout the season. The players´ average variability throughout the season was 5.1% for the jump spike and 4.2% for the standing spike. The proposed protocol allows coaches to assess the evolution of the different players and helps them to individualize the monitoring they carry out.

Keywords: team sports, performance, training, monitoring, feedback

INTRODUCTION

Coaches monitor athletes´ training in an attempt to supervise and orient this process to improve the athletes´ abilities and skills (31). Performance assessment tends to use tests that are specific to a certain sport and that provide immediate feedback (31). Tests that do not provide immediate feedback are used only when there is no other way to directly obtain the information that the tests provide or when they allow for a more detailed analysis (e.g. blood analysis or biomechanical analysis of movements) (22, 31). The main objective of monitoring training and competition is to provide information about athletes and teams in practice and competition.

Coaches complement the continual assessment of their athletes by having their athletes perform occasional tests to monitor their training and/or competition (31). The use of technology (e.g. cameras, software, etc.) facilitates the performance of these tests in training as well as the continual assessment that coaches and support staff carry out. For sports in which the speed of execution determines the success of the game actions, measurement protocols that are easily applied and that offer information about the players´ useful strength as well as the mechanical execution of the movements (e.g. baseball pitch, basketball shot, volleyball spike) are necessary (28). This information allows researchers to establish the athlete´s needs as well as to monitor the training goals.

In volleyball, the spike is the game action that attains the most points and that has the highest correlation to the team´s performance in competition (19, 24). The performance of the spike, from a mechanical viewpoint, depends on the height of contact, the direction the ball is sent, and the release speed of the ball (adapted from Gutiérrez et al. 13). Monitoring jump heights and reach heights is common in training (11, 21, 33). Likewise, monitoring the spike direction while taking into account the attack zone, the attack tempo, etc., is common practice in training and competition (23, 25). However, monitoring the spike speed is less frequently done in training. This is likely due to the fact that the necessary instrument (i.e. a radar) is not very common in the sport environment (37). There are theoretical proposals for protocols to monitor spike speed in the bibliography (8, 27). In the scientific literature, there are transversal studies that give reference values for male volleyball players´ ball speed for the spike in different categories, such as elite (4, 6, 10, 16, 32), semiprofessional or university (2, 10, 20, 29), and youth or amateur (18, 32). Likewise, there are similar studies for female players of elite (4, 5, 7, 9, 15, 30, 32), semiprofessional or university (2, 38), and youth or amateur categories (1, 3, 12, 14).

No studies were found that provide information about protocols or reference values for monitoring the spike speed longitudinally throughout the season. In the bibliography review that was carried out, no applied research proposals were found about how to monitor spike speed and how to employ this information within the dynamics of a team´s work routines. This study tests a monitoring protocol that can be included in the normal training dynamics of any volleyball team, and it provides reference values for monitoring spike training in volleyball. The aim of this study was to test the viability of monitoring the evolution of the spike speed for female volleyball players throughout a season.

METHODS

The sample comprised 10 players from a women´s volleyball team in Spain´s first division. Nine of the 10 players competed with their respective country´s national team. All players participated voluntarily, none had chronic shoulder injuries, and they all signed the informed consent form before beginning. The study was approved by the university´s Ethics Committee, the club, and the team´s coaching staff. Players´ mean age was 23.9 (±5.5) years, their average training experience was 11.2 (±6.1) years, their mean height was 1.82 (±0.05) meters, their mean weight was 73.6 (±4.9) kg, and their mean reach was 2.34 (±0.06) m.

A descriptive, correlational, repeated-measures study was carried out. The variables were the ball speed in the standing spike test (i.e. hitting without a jump) and in the jump

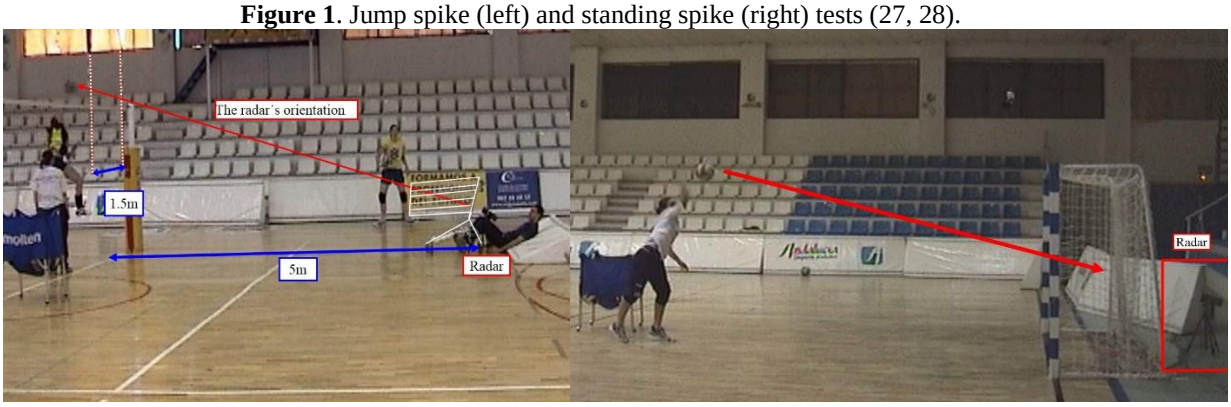
spike test (28). The speed data were recorded for 23 weeks of the competition, including the first 9 weeks of the season, the second 9 weeks of the season, and the 5 weeks of play-offs. The standing and jump spike speeds were recorded twice each week through a series of five trials (Table 1). In total, between 175 and 205 recordings were registered for each player for the standing and jump spike tests, respectively. It was not possible to carry out the tests on every day that was initially programmed due to the following reasons: the competition calendar changed throughout the season, the team participated in the Queen´s Cup, some players suffered injuries, and some players attended team training with their respective national teams.

Ball speed was recorded in kilometers per hour (km/h). From the recorded values, the degree of variability of the players´ actions was calculated. The test performance was integrated into the team´s training routine. The jump spike and standing spike tests were carried out at the beginning and the end of practice, respectively, on the second and fourth days of the week. All of the jump spike assessments were done at the same time of day, in the same place, and after carrying out the team´s warm-up (i.e. jogging, active stretching and joint mobility exercises, and exercises with the ball such as partner pepper and spiking at the net). All of the standing spike assessments were carried out after the practice session was finished, in the same place. The coach determined the order in which the players performed the tests. The protocol for executing the tests was that proposed by Palao and Valades (28) (Figure 1). A member of the coaching staff assured the correct performance of the tests. When any aspect of the execution was not done properly (e.g. sending the ball outside of the marked area), the trial was considered null, and it was repeated up to a maximum of seven times per series. The pressure of the ball was monitored to assess the energy lost in the transfer of the hit. Likewise, the adequate orientation of the radar (35) and calibration of the radar were monitored.

Table 1. Days measured and measurements done during the study periods by player.

Player	Period I (9 weeks)		Period II (9 weeks)		Period III (5 weeks)	
	Days measured	Measurements	Days measured	Measurements	Days measured	Measurements
1	16	80	18	90	7	35
2	16	80	18	90	7	35
3	16	80	14	70	7	35
4	16	80	18	90	7	35
5	15	75	18	90	7	35
6	15	75	13	65	7	35
7	15	75	18	90	5	25
8	16	80	18	90	7	35
9	15	75	18	90	7	35
10	16	80	18	90	7	35
Total	156	780	171	855	68	340

Figure 1. Jump spike (left) and standing spike (right) tests (27, 28).



The instruments utilized in the study included: a Radar Stalker pro (Applied Concepts, Inc, Texas, U.S.A.), a tripod with a support for a radar, and a Mikasa MVP-200 ball. To monitor the test performances and possible external variables, a manometer (Imsport, Spain), a data registry sheet, and a laser pointer were used to orient the radar toward the zone where the hand contacts the ball.

A descriptive and inferential analysis was carried out with the SPSS (IBM, U.S.A.) software. Means, standard deviation, maximum values, minimum values, and percentage of variability were calculated for the descriptive analysis. For the inferential analysis, to study the variability of the measurements, the non-parametric Friedman test and the linear regression of the repeated measures for the entire season and for the different periods were carried out for the team as well as for each player. A post-hoc analysis utilizing the non-parametric paired-sample Wilcoxon test was done between each of the phases of competition, with the goal of testing whether there were changes between each period.

RESULTS

In tables 2 and 3, the standing spike and jump spike speeds for each player throughout the 23 weeks of the competitive period are presented. The maximum recorded speed for the jump spike was 82 km/h, and the highest variability of the mean speed attained by a player when compared to the mean maximum value was 13%. The maximum recorded speed for the standing spike was 86 km/h, and the highest variability of the mean speed attained by a player when compared to the mean maximum was 15%.

In figure 2, three examples of the evolution of the jump spike´s speed throughout the season are included. These graphs demonstrate a gradual increase in the spike speed of a 19-year-old player, stability throughout the season for a 22-year-old player, and a gradual decrease in the spike speed of a 27-year-old player.

Table 2. Means, standard deviation, maximums, minimums, and variability between weeks for the jump spike speed during the competitive period of a high performance women's volleyball team

Player/Week		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23
	X	74.6	73.5	74.2	72.0	69.2	76.6	75.0	74.1	74.1	72.6	72.2	73.5	74.2	73.9	73.9	74.9	75.1	74.0	74.4	77.8	75.6	75.4	73.9
	SD	1.8	3.5	3.2	2.0	8.5	3.2	5.2	3.1	2.5	1.9	2.8	2.5	2.3	2.8	3.7	3.2	4.4	2.6	2.8	1.5	3.1	1.8	4.8
1	Max	77.0	78.0	78.0	75.0	78.0	82.0	82.0	79.0	79.0	76.0	77.0	77.0	77.0	78.0	79.0	80.0	*82.0*	79.0	80.0	80.0	79.0	78.0	81.0
	Min	71.0	68.0	67.0	70.0	56.0	73.0	70.0	67.0	70.0	69.0	68.0	70.0	70.0	71.0	68.0	69.0	68.0	70.0	71.0	76.0	71.0	73.0	67.0
	Var (%)		99%	99%	97%	*93%*	**100%**	98%	97%	97%	95%	94%	96%	97%	96%	96%	98%	98%	97%	97%	**100%**	97%	97%	95%
	X	61.8	63.5	62.7	59.8	61.3	62.7	62.4	62.8	62.9	61.4	65.0	60.8	62.9	64.3	68.0	64.8	63.4	63.0	63.7	64.6	59.2	62.8	64.9
	SD	4.3	3.5	3.2	3.2	3.1	1.4	2.6	3.2	1.9	2.6	1.4	2.3	2.6	3.1	2.1	3.0	3.2	2.2	1.6	1.1	4.7	1.1	1.9
2	Max	66.0	69.0	67.0	64.0	65.0	65.0	66.0	68.0	64.0	65.0	68.0	64.0	67.0	69.0	71.0	69.0	67.0	66.0	66.0	66.0	65.0	64.0	68.0
	Min	52.0	59.0	58.0	56.0	56.0	60.0	60.0	57.0	58.0	57.0	63.0	57.0	58.0	58.0	65.0	60.0	58.0	60.0	61.0	63.0	54.0	62.0	61.0
	Var%		**100%**	99%	94%	97%	99%	98%	99%	99%	97%	**100%**	94%	97%	99%	**100%**	95%	93%	93%	94%	95%	***87%***	92%	95%
	X	67.5	72.8	73.9	75.0	68.5	72.7	70.2	66.6	68.1	69.3	69.3	69.5			68.6	65.7	69.6	69.6	74.0	69.4	66.4	67.2	68.9
	SD	6.3	3.6	2.8	3.5	6.2	3.4	2.6	5.2	4.8	4.5	3.3	2.9			4.2	4.2	3.8	3.4	3.5	5.2	6.7	4.5	3.7
3	Max	73.0	78.0	78.0	81.0	75.0	79.0	74.0	73.0	73.0	75.0	75.0	74.0			76.0	75.0	78.0	76.0	78.0	78.0	75.0	73.0	74.0
	Min	54.0	68.0	70.0	73.0	55.0	69.0	67.0	57.0	62.0	64.0	64.0	65.0			64.0	60.0	65.0	65.0	68.0	64.0	60.0	63.0	63.0
	Var%		**100%**	**100%**	**100%**	91%	97%	94%	89%	91%	92%	92%	93%			91%	*88%*	93%	93%	99%	93%	89%	90%	92%
	X	68.3	72.2	72.5	71.8	73.6	71.8	71.8	71.7	72.3	72.2	74.5	73.9	75.7	76.6	77.0	76.4	74.8	75.0	73.7	74.0	73.2	75.2	74.6
	SD	4.0	4.1	1.8	3.0	3.2	4.1	5.1	3.4	2.5	3.8	3.9	4.1	2.8	3.2	2.7	2.0	1.9	2.1	2.1	2.0	2.2	2.0	2.3
4	Max	75.0	76.0	75.0	76.0	77.0	80.0	77.0	77.0	77.0	78.0	81.0	81.0	80.0	80.0	81.0	79.0	78.0	79.0	77.0	77.0	76.0	77.0	77.0
	Min	63.0	62.0	68.0	68.0	68.0	65.0	64.0	67.0	68.0	66.0	69.0	68.0	70.0	71.0	71.0	73.0	72.0	71.0	71.0	72.0	70.0	72.0	70.0
	Var%		**100%**	**100%**	99%	**100%**	98%	98%	97%	98%	98%	**100%**	99%	**100%**	**100%**	**100%**	99%	97%	97%	96%	96%	*95%*	*98%*	97%
	X	71.6	72.9	72.1	73.4	71.0	72.4	72.2	70.3	70.2	73.1	72.7	70.1	74.4	72.4	76.1	73.6		70.8	74.9	76.0	74.6	72.0	72.0
	SD	4.3	3.3	2.0	3.4	3.1	1.8	2.2	2.9	4.6	2.5	2.7	2.8	2.4	4.9	3.3	4.2		2.4	2.8	1.9	3.2	2.4	3.1
5	Max	77.0	77.0	76.0	77.0	75.0	76.0	75.0	74.0	77.0	77.0	76.0	73.0	77.0	79.0	82.0	78.0		74.0	80.0	78.0	79.0	75.0	77.0
	Min	62.0	67.0	68.0	69.0	68.0	70.0	70.0	66.0	61.0	69.0	68.0	64.0	71.0	62.0	70.0	68.0		68.0	70.0	74.0	70.0	69.0	65.0
	Var%		**100%**	99%	**100%**	97%	99%	98%	96%	96%	**100%**	99%	96%	**100%**	97%	**100%**	97%		*93%*	98%	**100%**	98%	95%	95%
	X	64.2	68.7	70.3	70.8	69.1	69.0	68.2	72.5	73.7	73.7	73.8	75.7	76.3	75.0	76.5	75.5	74.7	75.9	76.9	74.4	73.0	74.2	77.5
	SD	4.6	4.0	4.5	3.9	3.9	5.7	3.7	4.6	2.2	3.8	3.2	3.1	2.8	1.8	3.7	3.0	3.2	3.5	2.6	3.4	2.8	3.7	2.9
6	Max	71.0	73.0	75.0	76.0	75.0	74.0	73.0	77.0	77.0	79.0	79.0	81.0	81.0	77.0	82.0	80.0	82.0	*82.0*	81.0	78.0	76.0	80.0	*82.0*
	Min	57.0	61.0	60.0	67.0	61.0	60.0	64.0	65.0	70.0	69.0	70.0	71.0	73.0	72.0	71.0	70.0	70.0	71.0	72.0	70.0	70.0	70.0	73.0
	Var%	0.0	**100%**	**100%**	**100%**	98%	97%	96%	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	98%	**100%**	99%	98%	99%	**100%**	97%	*95%*	96%	**100%**
	X	65.4	72.8	72.8	74.4	73.6	72.5	72.6	69.8	74.4	72.3	74.1	74.5	75.5	73.4	76.0	76.9	74.4	74.6	73.2	74.6		73.8	72.9
	SD	2.2	2.6	3.8	1.9	3.7	3.0	1.8	1.7	3.3	3.0	3.2	3.7	3.7	1.9	3.2	2.6	2.0	2.0	3.1	3.2		2.4	3.3
7	Max	68.0	77.0	77.0	77.0	81.0	77.0	75.0	72.0	79.0	77.0	78.0	80.0	82.0	77.0	80.0	80.0	78.0	77.0	77.0	78.0		76.0	79.0
	Min	62.0	70.0	66.0	72.0	69.0	68.0	70.0	67.0	70.0	68.0	68.0	70.0	70.0	71.0	70.0	72.0	70.0	72.0	70.0	70.0		70.0	70.0
	Var%		100%	100%	100%	99%	97%	98%	*94%*	**100%**	97%	**100%**	**100%**	**100%**	97%	**100%**	**100%**	97%	97%	95%	97%		96%	95%
	X	69.1	70.1	71.9	74.2	71.5	75.9	73.6	73.8	72.9	73.1	75.4	73.6	75.4	75.3	75.8	73.7	74.3	76.3	76.0	76.4	73.6	76.4	75.3
	SD	3.3	4.3	6.2	4.0	5.1	2.8	2.6	2.8	4.1	4.0	3.5	3.8	2.7	2.1	3.8	2.8	2.8	3.4	2.7	3.0	1.7	3.8	3.4
8	Max	73.0	77.0	79.0	79.0	79.0	79.0	76.0	78.0	79.0	78.0	80.0	80.0	80.0	78.0	81.0	78.0	79.0	81.0	81.0	81.0	75.0	81.0	80.0
	Min	64.0	61.0	61.0	69.0	63.0	70.0	70.0	70.0	67.0	68.0	70.0	67.0	71.0	72.0	70.0	70.0	70.0	71.0	72.0	73.0	71.0	72.0	70.0
	Var%		**100%**	**100%**	**100%**	96%	**100%**	97%	97%	*96%*	*96%*	99%	97%	99%	99%	**100%**	97%	98%	**100%**	**100%**	**100%**	*96%*	**100%**	99%
	X	64.8	64.7	68.9	70.0	65.8	66.0	68.2	65.1	63.8	68.7	66.2	66.8	70.7	70.2	70.6	69.1	70.2	71.9	70.9	69.8	69.6	69.8	70.5
	SD	3.3	4.7	3.3	3.7	3.3	5.4	3.6	3.1	3.9	3.8	3.8	2.2	0.9	3.3	2.3	3.8	2.9	2.1	1.6	3.6	2.6	0.8	2.5
9	Max	68.0	70.0	73.0	73.0	71.0	71.0	71.0	68.0	70.0	73.0	72.0	70.0	72.0	75.0	75.0	72.0	73.0	75.0	74.0	74.0	72.0	71.0	76.0
	Min	57.0	57.0	62.0	66.0	62.0	56.0	62.0	58.0	57.0	62.0	60.0	64.0	69.0	65.0	67.0	60.0	65.0	69.0	69.0	66.0	66.0	69.0	67.0
	Var%		**100%**	**100%**	**100%**	94%	94%	97%	93%	*91%*	98%	95%	95%	**100%**	99%	**100%**	98%	99%	**100%**	99%	97%	97%	97%	98%
	X	72.4	71.9	69.8	73.0	71.1	70.5	70.0	70.1	69.2	72.4	71.5	71.6	72.2	68.5	72.1	70.3	69.1	68.7	69.0	65.8	68.8	63.4	66.0
	SD	4.2	4.3	2.9	3.1	3.3	3.2	3.1	1.6	3.0	3.1	1.5	1.9	1.8	4.9	2.0	4.3	4.7	2.5	4.0	2.6	3.3	3.0	2.4
10	Max	78.0	77.0	73.0	77.0	77.0	75.0	75.0	72.0	73.0	76.0	73.0	75.0	75.0	78.0	75.0	76.0	76.0	73.0	77.0	69.0	74.0	68.0	68.0
	Min	65.0	66.0	64.0	70.0	67.0	65.0	67.0	67.0	65.0	66.0	69.0	70.0	70.0	62.0	69.0	64.0	63.0	65.0	64.0	63.0	66.0	61.0	61.0
	Var%		99%	96%	**100%**	97%	97%	96%	96%	95%	99%	98%	98%	99%	94%	99%	96%	95%	94%	95%	90%	94%	***87%***	90%

Table 3. Means, standard deviation, maximums, minimums, and variability between weeks for the standing spike speed during the competitive period of a high performance women's volleyball team

Player/Week		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23
	X	76.0	77.5	73.0	75.6	66.2	76.1	76.8	72.2	75.8	73.4	71.8	75.6	73.6	68.3	73.0	75.1	77.2	76.0	73.6	72.0	71.6	73.6	71.0
	SD	4.5	3.0	2.8	4.7	4.2	4.5	4.0	2.7	2.7	3.3	3.4	3.5	2.2	4.2	2.2	3.4	1.8	2.9	2.6	3.0	2.3	2.3	2.8
1	Max	79.0	80.0	77.0	83.0	74.0	83.0	83.0	77.0	79.0	79.0	76.0	82.0	77.0	76.0	78.0	80.0	80.0	80.0	79.0	76.0	74.0	77.0	76.0
	Min	66.0	73.0	68.0	71.0	58.0	68.0	70.0	66.0	72.0	68.0	64.0	70.0	70.0	64.0	71.0	70.0	75.0	72.0	70.0	69.0	69.0	71.0	67.0
	Var%		**100%**	94%	98%	***85%***	98%	99%	93%	98%	95%	93%	98%	95%	88%	94%	97%	**100%**	98%	95%	93%	92%	95%	92%
	X	63.5	63.8	63.4	59.2	63.3	60.4	58.7	61.0	58.7	58.6	60.2	57.5	60.3	62.5	62.8	61.0	60.1	59.8	60.1	60.0	59.0	58.8	61.7
	SD	3.3	1.9	5.0	1.6	5.1	2.2	1.3	1.6	2.9	2.5	1.4	3.3	1.6	2.7	2.7	3.3	2.2	1.9	3.8	1.4	2.0	3.3	1.4
2	Max	69.0	66.0	73.0	61.0	73.0	64.0	61.0	63.0	63.0	63.0	62.0	64.0	64.0	68.0	66.0	68.0	63.0	62.0	64.0	62.0	61.0	62.0	64.0
	Min	59.0	60.0	57.0	57.0	59.0	58.0	57.0	58.0	54.0	56.0	58.0	53.0	58.0	60.0	57.0	56.0	56.0	57.0	54.0	58.0	56.0	54.0	60.0
	Var%		**100%**	99%	93%	99%	95%	92%	96%	92%	92%	94%	*90%*	95%	98%	98%	96%	94%	94%	94%	94%	92%	92%	97%
	X	66.0	66.7	65.7	62.0	66.7	64.4	66.4	61.6	65.5	69.2	68.3	69.3			61.5	62.3	63.9	64.8	65.7	61.8	63.2	62.2	66.4
	SD	5.7	4.5	4.5	5.3	2.5	3.8	3.4	3.6	2.8	4.0	2.2	5.4			4.1	4.3	3.6	3.4	4.2	2.0	4.6	3.7	3.2
3	Max	73.0	71.0	73.0	68.0	70.0	71.0	71.0	70.0	69.0	73.0	72.0	77.0			68.0	67.0	68.0	72.0	71.0	65.0	70.0	65.0	71.0
	Min	56.0	56.0	60.0	55.0	62.0	57.0	60.0	57.0	60.0	61.0	65.0	60.0			55.0	54.0	57.0	60.0	59.0	60.0	60.0	56.0	62.0
	Var%		**100%**	99%	93%	**100%**	97%	**100%**	92%	98%	**100%**	99%	**100%**			*89%*	90%	92%	94%	95%	89%	91%	90%	96%
	X	74.4	75.7	73.6	77.0	75.0	75.7	74.9	73.6	73.7	76.6	77.9	76.1	76.4	79.1	78.2	79.8	78.2	77.9	75.8	73.4	78.8	79.4	76.9
	SD	3.1	1.8	2.2	1.2	2.4	2.2	1.9	2.3	2.5	2.6	2.0	3.5	1.5	2.8	1.9	0.9	2.4	2.2	1.5	3.4	1.6	2.2	2.5
4	Max	78.0	78.0	77.0	78.0	79.0	79.0	79.0	78.0	79.0	80.0	80.0	81.0	79.0	83.0	81.0	81.0	82.0	81.0	78.0	79.0	80.0	81.0	81.0
	Min	69.0	72.0	70.0	75.0	70.0	73.0	73.0	71.0	71.0	71.0	74.0	70.0	74.0	73.0	76.0	78.0	75.0	73.0	74.0	70.0	76.0	77.0	73.0
	Var%		**100%**	97%	**100%**	97%	98%	97%	96%	96%	99%	**100%**	98%	98%	**100%**	99%	**100%**	98%	98%	95%	*92%*	99%	99%	96%
	X	65.8	68.3	67.8	69.2	67.8	66.3	67.2	68.6	68.7	68.4	68.9	69.0	70.9	70.4	72.2	71.6		70.0	70.0	72.2	69.2	71.8	71.0
	SD	4.2	2.2	1.8	1.3	2.3	1.6	1.8	1.5	4.0	1.7	2.5	1.2	1.7	2.0	1.8	0.5		1.4	1.9	0.8	2.2	1.3	1.7
5	Max	71.0	70.0	70.0	71.0	71.0	69.0	70.0	70.0	73.0	71.0	72.0	72.0	73.0	73.0	75.0	72.0		72.0	72.0	73.0	71.0	73.0	73.0
	Min	56.0	63.0	65.0	68.0	64.0	64.0	65.0	66.0	60.0	66.0	63.0	68.0	68.0	66.0	69.0	71.0		68.0	66.0	71.0	66.0	70.0	68.0
	Var%		**100%**	99%	**100%**	98%	*96%*	97%	99%	99%	99%	**100%**	**100%**	**100%**	99%	**100%**	99%		97%	97%	**100%**	96%	99%	98%
	X	72.9	66.2	70.7	71.8	68.3	72.0	72.7	64.6	72.2	67.7	72.2	71.1	70.1	70.6	73.3	70.5	73.3	72.2	73.7	74.2	69.6	71.8	72.5
	SD	5.2	4.0	5.2	2.3	6.2	5.7	4.0	3.3	2.3	4.1	2.3	1.7	2.5	2.8	1.4	3.2	2.5	2.4	1.8	2.8	1.8	1.1	1.4
6	Max	79.0	72.0	77.0	74.0	79.0	79.0	79.0	70.0	75.0	72.0	76.0	73.0	74.0	74.0	76.0	75.0	77.0	76.0	76.0	77.0	72.0	73.0	75.0
	Min	64.0	60.0	62.0	68.0	60.0	61.0	67.0	60.0	68.0	61.0	68.0	68.0	65.0	66.0	72.0	63.0	70.0	69.0	70.0	70.0	67.0	70.0	70.0
	Var%		91%	97%	98%	94%	99%	**100%**	*89%*	99%	93%	99%	98%	96%	97%	**100%**	96%	**100%**	98%	**100%**	**100%**	94%	97%	98%
	X	80.0	77.7	81.1	79.8	77.7	77.9	76.4	79.3	81.6	77.9	79.9	79.8	78.3	77.9	80.7	81.6	81.9	81.1	81.6	78.4		77.6	80.4
	SD	3.2	4.1	2.2	1.5	2.7	3.1	3.1	3.1	2.0	3.5	2.7	2.0	2.3	3.1	4.2	2.5	3.7	3.0	2.8	2.5		1.5	3.7
7	Max	83.0	81.0	*86.0*	82.0	82.0	82.0	81.0	84.0	85.0	83.0	83.0	83.0	84.0	82.0	85.0	83.0	*86.0*	85.0	85.0	82.0		80.0	85.0
	Min	75.0	68.0	79.0	78.0	73.0	73.0	73.0	74.0	79.0	72.0	73.0	77.0	76.0	73.0	72.0	75.0	73.0	75.0	75.0	76.0		76.0	75.0
	Var%		97%	**100%**	98%	96%	96%	*94%*	98%	**100%**	95%	98%	98%	96%	95%	99%	**100%**	**100%**	99%	**100%**	96%		95%	98%
	X	75.1	75.7	70.2	71.8	73.3	73.8	70.0	72.6	75.5	73.9	75.3	76.0	74.5	74.2	73.8	73.2	75.7	71.7	73.9	73.2	68.4	74.6	75.0
	SD	1.9	2.1	3.6	1.3	1.6	2.0	3.9	2.5	1.5	2.0	2.3	4.4	2.2	1.9	0.8	1.8	4.2	4.2	2.6	1.9	2.3	1.1	3.0
8	Max	78.0	78.0	75.0	73.0	75.0	77.0	75.0	75.0	78.0	77.0	79.0	81.0	78.0	76.0	75.0	76.0	81.0	77.0	77.0	75.0	71.0	76.0	79.0
	Min	72.0	72.0	63.0	70.0	70.0	70.0	64.0	67.0	73.0	70.0	72.0	68.0	70.0	71.0	73.0	70.0	70.0	63.0	70.0	70.0	65.0	73.0	70.0
	Var%		**100%**	93%	95%	97%	97%	*92%*	96%	**100%**	98%	99%	**100%**	98%	98%	97%	96%	**100%**	94%	97%	96%	90%	98%	99%
	X	69.7	68.3	70.5	70.0	71.0	69.4	69.9	68.9	69.8	68.8	70.3	70.5	70.5	70.1	70.1	69.3	72.0	70.5	68.9	71.6	72.4	69.8	70.4
	SD	3.7	3.3	3.3	1.9	1.6	2.7	2.2	1.6	3.1	4.5	1.9	2.8	1.4	2.8	1.4	2.0	3.3	2.2	3.0	0.9	4.3	2.2	2.6
9	Max	73.0	73.0	77.0	72.0	73.0	73.0	73.0	71.0	74.0	75.0	73.0	75.0	73.0	74.0	72.0	73.0	77.0	73.0	72.0	72.0	76.0	73.0	74.0
	Min	60.0	62.0	65.0	68.0	69.0	64.0	66.0	66.0	66.0	63.0	68.0	65.0	69.0	66.0	67.0	65.0	68.0	66.0	65.0	70.0	65.0	67.0	67.0
	Var%		98%	**100%**	99%	**100%**	98%	98%	97%	98%	97%	99%	99%	99%	99%	99%	98%	**100%**	98%	96%	99%	**100%**	*96%*	97%
	X	70.5	70.6	69.7	68.2	66.8	69.8	70.9	68.4	66.2	66.5	67.4	67.3	65.2	66.8	69.5	67.6	67.6	68.1	67.3	63.2	68.0	64.4	68.0
	SD	3.1	1.9	1.8	1.6	4.8	3.0	1.9	1.8	3.7	3.0	1.8	3.5	1.6	3.1	2.4	2.9	2.6	3.0	3.4	3.3	0.0	2.7	3.5
10	Max	74.0	73.0	72.0	70.0	77.0	74.0	74.0	71.0	72.0	72.0	70.0	71.0	68.0	71.0	72.0	71.0	71.0	72.0	72.0	68.0	68.0	67.0	72.0
	Min	65.0	68.0	67.0	67.0	60.0	64.0	68.0	65.0	60.0	61.0	64.0	60.0	63.0	62.0	64.0	63.0	64.0	63.0	61.0	60.0	68.0	61.0	61.0
	Var%		**100%**	99%	97%	95%	99%	**100%**	96%	93%	94%	95%	95%	92%	94%	98%	95%	95%	96%	95%	*89%*	96%	91%	96%

Figure 2. Three examples of the evolution of the players´ spike speed: mean, maximum, and percentage of variability.

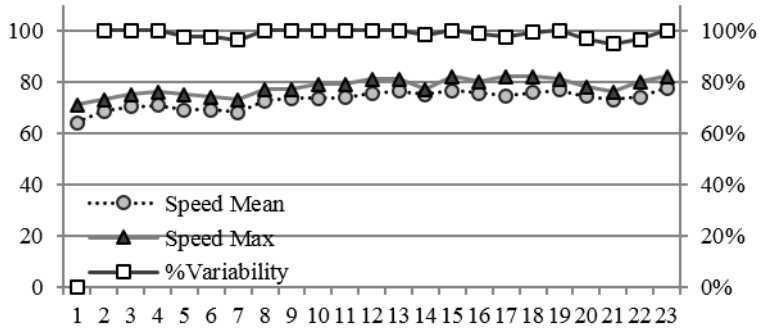
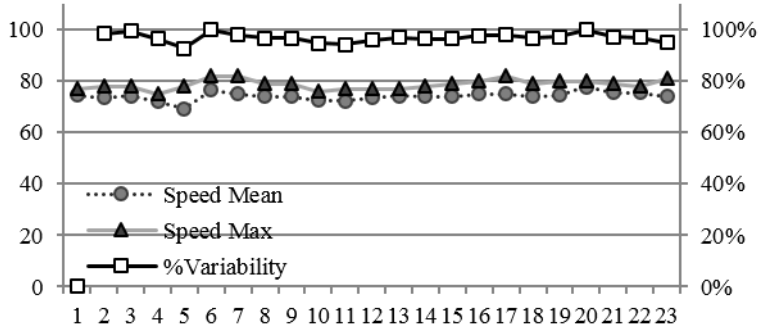
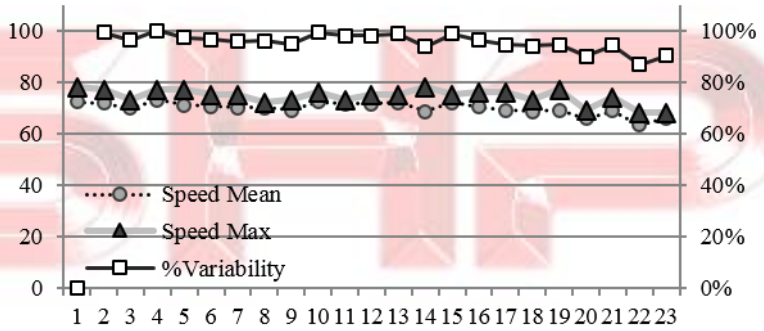
Age	Tendency	Graph
19 years	Improvement	
22 years	Stability	
27 years	Decline	

Table 4. Mean (X), standard deviation (SD), linear regression slope (B), and percentage of variability of the jump spike and standing spike speeds throughout the season.

	JUMP SPIKE					STANDING SPIKE				
Player	X/SD		B(p)	%Var/SD		X/SD		B(p)	%Var/SD	
1	74.0	±3.7º	0.42*	95.27	±1.8	73.6	±4.2º	-0.03	95.1	±3.6
2	63.1	±3.1º	**0.55****	92.63	±3.3	60.8	±3.2ººº	**−0.06****	95.0	±2.8
3	69.7	±4.8º	−0.05*	92.88	±3.9	65.2	±4.5ººº	−0.05	93.7	±4.1
4	73.6	±3.6ºº	**0.12*****	95.58	±1.6	76.4	±2.9º	**0.09*****	95.8	±2.0
5	72.6	±3.4	**0.05***	95.50	±2.1	69.2	±2.7ººº	**0.12*****	96.0	±1.4
6	73.2	±4.8ººº	**0.24*****	94.23	±1.6	70.9	±4.0º	**0.09*****	95.8	±3.1
7	73.6	±3.4	**0.09*****	95.43	±2.0	79.6	±3.2	**0.05***	97.0	±1.9
8	74.0	±4.0ºº	**0.13*****	96.95	±1.5	73.7	±3.2º	0.01	96.8	±2.6
9	68.3	±3.9ººº	**0.15*****	95.08	±2.6	70.0	±2.8	**0.03***	96.8	±1.2
10	70.1	±3.7ººº	**−0.11*****	95.74	±3.3	67.8	±3.2ººº	**−0.07*****	95.5	±2.7
Team	71.2	±5.1ººº	**0.37*****	94.90	±2.9	70.7	±6.2º	0.07	95.8	±3.0

Legend: Significance of the Friedman test: º p<0.5, ººp<0.1, ºººp<0.001. Significance of the linear regression: * p<0.5, **p<0.1, ***p<0.001

Table 5. Means (X), standard deviation (SD), linear regression slope (B), and percentage of variability (%Var) for the jump spike speeds by period (I, II, & III).

	I		II		III		I		II		III	
Player	X/SD	B(p)	X/SD	B(p)	X/SD	B(p)	%Var/SD		%Var/SD		%Var/SD	
1	73.7 ±4.4	0.04	73.8 ±3.0	**0.15***	75.1 ±3.4[2]	-0.20	94.8	±2.4	94.9	±1.2	96.9	±1.8
2	62.4 ±3	0.03	63.7 ±3.2[1]	**0.13***	63.4 ±2.8[2]	0.14	91.5	±1.9	93.7	±2.9	92.7	±3.4
3	70.3 ±5.3	-0.22	68.8 ±3.9	-0.07	69.8 ±5.1	**−1.14*****	94.1	±4.6	91.7	±1.9	92.2	±3.9
4	71.8 ±3.6	0.13	75.1 ±3.2[1]	**0.16***	74.1 ±2.1[1]	0.25	93.2	±1.3	97.6	±1.2	96.3	±1.0
5	71.7 ±3.2	-0.13	72.9 ±3.6	0.05	73.8 ±3.1	**−0.72*****	94.3	±1.6	95.8	±2.5	97.1	±2.4
6	69.7 ±4.8	**0.47*****	75.2 ±3.2[1]	0.09	75.8 ±3.3[1]	0.14	89.8	±1.6	97.1	±0.9	97.0	±2.3
7	72.3 ±3.6	0.16	74.6 ±3.1	**0.13***	73.5 ±3.0	−0.11	93.7	±2.3	97.1	±1.5	95.7	±1.0
8	72.4 ±4.5	**0.32****	74.8 ±3.3[1]	0.09	75.6 ±3.0[1]	-0.09	95.0	±1.7	97.9	±1.4	98.9	±1.6
9	66.0 ±4.2	-0.07	69.4 ±3.3[1]	**0.25*****	70.3 ±2.2[12]	-0.21	92.3	±3.1	96.5	±2.0	97.5	±0.8
10	70.8 ±3.3	**-0.18***	70.7 ±3.4	**−0.22****	66.9 ±3.6[12]	-0.48	97.1	±1.6	96.9	±2.2	91.2	±3.2
Team	70.1 ±5.2	0.05	72.0 ±4.9[1]	0.08*	71.8 ±5.1[12]	-0.03	93.6	±2.6	95.9	±2.6	95.6	±3.3

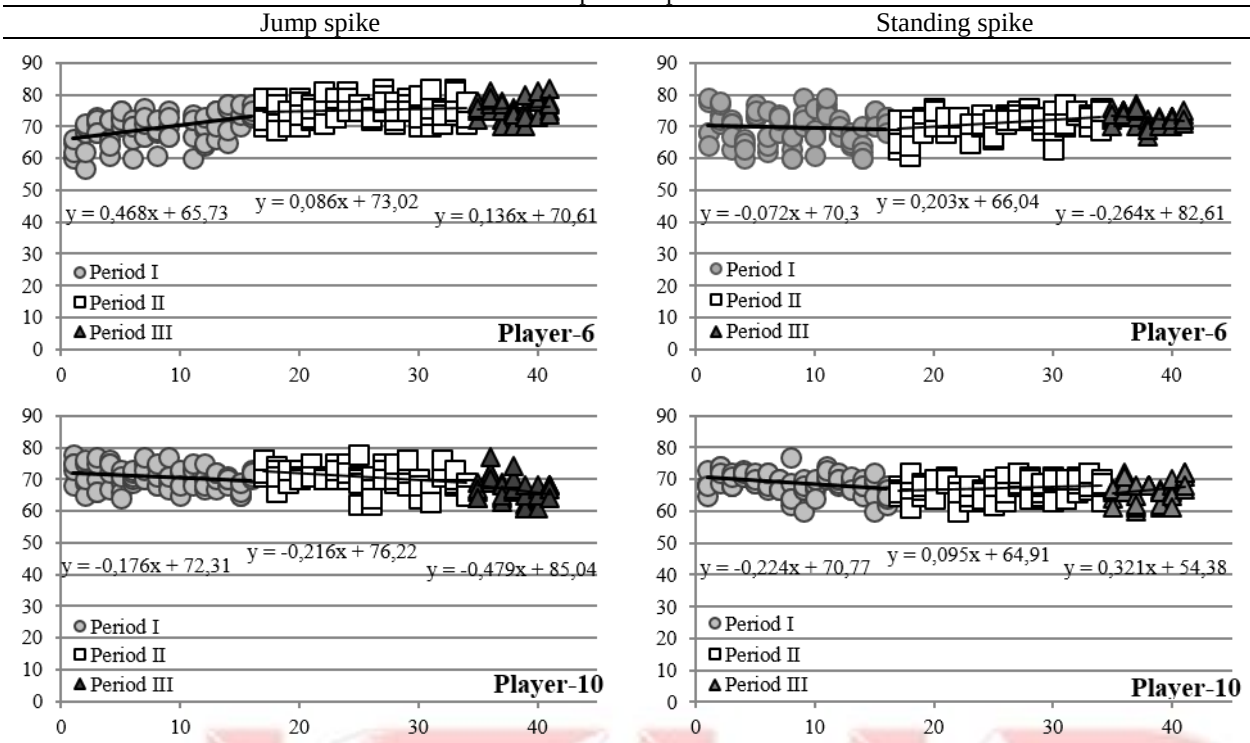
Legend: The Wilcoxon test between periods demonstrates significance: [1] with period I, [2] with period II. The linear regression for each period demonstrates significance: * p<0.5, **p<0.1, ***p<0.001

Table 6. Means (X), standard deviation (SD), linear regression slope (B), and percentage of variability (%Var) for the standing spike speeds by period (I, II, and III).

	I		II		III		I		II		III	
Player	X/SD	B(p)	X/SD	B (p)	X/SD	B (p)	%Var/SD		%Var/SD		%Var/SD	
1	74.1 ±4.8	-0.11	73.8 ±3.9	0.21**	72.3 ±2.7[1]	-0.39	95.9	±5.1	95.2	±3.4	93.4	±1.5
2	61.6 ±3.7	−0.35***	60.3 ±2.8	0.18*	60.2 ±2.7[1]	0.32	96.1	±3.3	94.5	±2.6	93.9	±2.8
3	65.1 ±4.3	-0.17	65.6 ±4.9	−0.41***	64.5 ±3.9[2]	0.25	93.8	±3.3	94.7	±4.8	92.2	±3.0
4	74.7 ±2.4	-0.07	77.8 ±2.5[1]	0.13**	76.7 ±2.8[1]	0.40	93.8	±1.6	97.5	±1.0	96.3	±3.0
5	67.8 ±2.7	0.12	70.1 ±2.1[1]	0.20***	70.7 ±1.9[12]	0.16	93.8	±1.6	97.2	±1.0	98.1	±1.7
6	69.7 ±5.2	-0.07	71.2 ±3.0[1]	0.20***	72.6 ±2.2[12]	-0.26	94.5	±4.3	96.0	±2.3	97.5	±2.6
7	79.2 ±3.2	0.05	79.9 ±3.3	0.21***	80.0 ±3.2	-0.21	96.5	±1.9	97.6	±1.8	97.1	±2.2
8	73.2 ±3.2	-0.08	74.3 ±3.1[1]	−0.12*	73.4 ±3.2[2]	0.34	96.2	±2.7	97.7	±1.8	96.1	±3.5
9	69.6 ±2.8	0.00	70.2 ±2.7	0.09	70.3 ±2.9	0.34	96.3	±1.1	97.0	±1.0	97.5	±1.9
10	68.9 ±3.2	−0.22**	67.3 ±2.8[1]	0.09	66.6 ±3.4[1]	0.32	97.3	±2.0	95.0	±1.7	93.3	±3.1
Team	70.3 ±6.0	−0.04**	71.2 ±6.4[1]	0.05	70.6 ±6.2	0.01	95.4	±3.0	96.2	±2.8	95.5	±2.8

Legend: The Wilcoxon test between periods demonstrates significance: [1] with period I, [2] with period II. The linear regression for each period demonstrates significance: * p<0.5, **p<0.1, ***p<0.001.

Figure 3. Example of the evolution of the speed for two players´ jump and standing spikes with regard to each competitive period.



In table 4, it is seen that for the team, the slope of the linear regression for the speed of the standing and jump spikes demonstrates an increase in the speeds of the jump spike and the standing spike, though it is only significant for the jump spike. The analysis of the slope of the regression by player demonstrates that for two of the 10 players, there was a decrease (i.e. loss of speed for the jump or standing spike throughout the season). The Friedman test indicates that there are differences between the speeds attained at the different competitive periods.

Overall values of the players´ evolution of speed and variability throughout the three competitive periods of the season are presented in tables 5 and 6. The results reveal that the evolution of the players in the two tests is different for each player at each period of the season. In general, it is observed that from the first to the third phase, eight players improved their jump spike speed an average of 2.7%. This increase was significant for four of them. For one player, there was a significant decrease in the jump spike speed. With regard to the standing spike speed, six players improved their speed an average of 1.6%. Four players decreased their speed an average of 1.5%. These speed losses were significant for three players. The slope of the linear regression demonstrates that for the team, the second competitive period was where the players reached their peak speeds. The play-off was the period where the lowest speeds were reached for the jump spike test, while the first competitive period was the period where the lowest speeds were reached for the standing spike test. Figure 3 demonstrates an example of the evolution of the slope for two players, and differences are observed with regard to the period and player. Likewise, the degree of dispersion of the data (i.e. the standard deviation) is also observed. It is further observed in figure 3 how the dispersion for player 6 decreases at the end of the first competitive period. Player 10 presents relatively stable dispersion throughout the season.

DISCUSSION

The aim of this study was to test a procedure to monitor the evolution of the speed of the standing and jump spikes for volleyball players throughout a season. The results present reference values for the evolution, peaks, and variability of spike speed in senior female volleyball players. The studied sample had slightly lower speed for the standing and jump spike tests than those found in previous studies with senior female volleyball players (~2-4 km/h) (15, 26, 30, 34). The proposed protocol for monitoring the speed of the standing and jump spikes allows us to assess the various tendencies that players have throughout the season. The analysis of these data provides information about the players´ ability to apply their upper strength and the effect of the training that is done. Variations in a player´s spike speed could show overload, or injury.

The differences between players show how they have assimilated the general strength training, specific strength training, and the regular practices and competitions that were carried out progressively and individually throughout the season. Along these lines, the different tendencies in the evolution of the athletes confirm the need to individualize the process of monitoring their training and the subsequent planning. The adaptations of the players to the training plan, the demands of the competition, and the individual characteristics of each player mean that their evolution is unique. This means that it is necessary to continually monitor the athlete to establish the effect of and the degree of assimilation of the work that is carried out as well as to monitor the accumulation of the weeks of training and competitions. This monitoring is traditionally carried out qualitatively by the coaches through observation of their athletes´ actions. The monitoring carried out in this study allows us to integrate an objective assessment of one of the aspects that affects the efficacy of the spike into the training routine and assess how it evolves throughout the season. The standing and jump spike tests may be employed together or separately depending on the characteristics of each team and its training. The standing spike test demonstrates the ability to apply force to the ball without temporal demands and without the effects of the jump or the net. The jump spike test demonstrates the ability to apply force in a more specific situation (28).

The tendencies and levels of variability that were found allow the coach to establish whether the athletes´ conditioning (fitness, overload, or injuries) regarding the spike varies throughout the season. This information can be obtained simply and can be automated in a spreadsheet both numerically and visually (means, slope, and degree of dispersion of the data). From this information, it can be established whether it is necessary to adapt the training in practice sessions due to, for example, pain, overtraining, etc. To serve as a reference, we recommend the use of 10% variability as the value to consider when players´ actions may be outside of their normal patterns. This value comes from the proposal by Izquierdo and González-Badillo (17) which established the maximum speed loss allowed in the execution of power training at 10%. Taking this value as a reference, it can be established in which weeks the players´ evolution of this skill is altered. The results demonstrate that the changes in the evolution are occasional in normal situations (4.2%-5.1%). Taking an example from this sample, player 1 presented a variability of 15% in week 5 due to a slight shoulder injury. This protocol for monitoring and analyzing the spike provides coaches and players with information regarding the evolution of the players´ spikes throughout the season as well as whether there is something affecting their performance. This information may help coaches in their analyses and decision making.

CONCLUSIONS

The results show the viability of integrating the standing and jump spike tests in regular practice in order to provide objective information which may help sports coaches and/or strength and conditioning coaches in their monitoring of performance-level players´ volleyball training (e.g. effect of training, overload, and injuries in their upper body). The information provided by these two tests is similar. Both tests allow us to assess the effect of the work that is carried out. The values found demonstrate the need to individualize the monitoring that goes on in training as well as the work to be carried out by the players.

Practical Applications

This study provides a protocol for monitoring and analyzing the speed of the spike as well as reference values for the speed and variability levels for the standing and jump spike tests. This type of monitoring provides objective information regarding the effect of technique training and physical training on the spike. This protocol provides an example of monitoring the spike speed which can help coaches monitor and analyze the objectives they set for their players and teams.

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