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Original Article

Combined practice and learning of movement pattern and precision of the volleyball serve in beginners

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Abstract: This study aimed to investigate the combined practice schedule on learning both the movement pattern and precision of a complex sports motor skill. Based on pretest performance, sixteen participants (14.19 ± 1.80 years-old) were counterbalanced into two groups, random practice and combined practice. During the acquisition phase, the participants performed 252 trials of the Japanese volleyball serve divided equally into six sessions. The score of movement pattern and score of serve precision measures were analyzed on the pretest and retention test. The results showed that combined practice led to movement pattern improvement, and random practice improved serve precision. These results give support to the proposition that movement patterns and parameters have distinct structures of control. Also, the results indicate that combined practice needs a higher amount of random practice to promote parameters improvement.

Keywords: motor skill; random practice; volleyball, hierarchical learning

1. Introduction

The organization of practice has received much attention in the last decades, which plays a key role in the improvement of motor skills. Practice organization can be constant or varied, and the latter received much attention from researchers in the last decades. Shea and Morgan (1979) first investigated the varied practice, comparing random and blocked practice. The authors found that although random practice, i.e., less repetitive practice, deteriorates performance during the learning phase, it is better for motor skills during the learning test when compared to blocked practice, i.e., more repetitive practice. This effect is known as the contextual interference effect. Based on this result, many researchers investigated the effects of varied practice on the learning of motor skills in the 1980s (Del Rey et al., 1983; Wulf & Schmidt, 1988).

The contextual interference effect is explained basically by two hypotheses, the elaborative-processing (Shea & Zimny, 1983) and the reconstruction hypothesis (Lee & Magill, 1983). Accordingly to the reconstruction hypothesis, the random practice conducts to the forgetfulness of the previous trial action plan. Consequently, the action plan has to be reconstructed from trial to trial strengthening the memory representation of the action. On the other hand, the elaborative-processing hypothesis proposes that the random practice improves the distinction between variations of the task improving the distinction in memory.

However, Wulf and Lee (1993) introduced parameters and movement structure skill measures, and subsequent studies investigated the relationship between random and blocked practice and what is learned. Most studies showed improvement in parameterization learning (Sekiya et al., 1994; Sekiya & Magill, 1996). The constant practice shows to improve movement structure, i.e., movement pattern (Giuffrida et al., 2002; Lai & Shea, 1998), and the varied practice improves parameterization. Based on these results, Lai et al. (2000) proposed that starting the practice with the constant practice followed by varied practice improved learning of movement pattern and parameterization of the skill, respectively. The findings about the order of practice were extended in other studies that investigate different varied practice (Lage et al., 2007) and variation of different aspects of the motor skill (Matos et al., 2017) and contextual interference studies diminished drastically (Barreiros, Figueiredo & Godinho, 2007). However, putting all the results together, the most repetitive practice (constant practice) improved spatiotemporal pattern of movement and later, the least repetitive practice (block or random varied practice) improved parameterization. These differences occur due to greater or lesser levels of trial-to-trial response stability, i.e., inter trials repeatability, promoted by each type of practice (Lelis-Torres et al., 2017). Lesser inter trials repeatability promotes greater cognitive engagement (Lage et al., 2015; Nee et al., 2013). Thus, the results found with combined practice are in accordance with the proposition about a hierarchy on programming a motor skill (Lashley, 1951; Summers, 1989).

Although providing practice sessions that optimize both aspects of sports motor skills was always considered a challenge, the studies cited before were run with simple lab tasks, with a few numbers of degrees of freedom. The principles from simple tasks not always can be generalized to sport motor skills (Wulf & Shea, 2002), indicating the importance of replicating the studies with simple lab tasks but now with complex motor skills (Christina, 1987). Some studies compared random and blocked practice with sports motor skills. For example, Goode and Magill (1986) compared blocked and random practice with the badminton serve in beginners, and Fialho et al. (2006) with the volleyball serve in athletes. In general, less than 50% of the studies confirmed the interference contextual effect (Barreiros, Figueiredo & Godinho, 2007).

Similar results were found more recently manipulating the increment in contextual interference in sports motor skills. For example, Buszard, Reid, Krause, Kovalichik and Farrow (2017) investigated the increment of contextual interference in skilled tennis players. While the low interference contextual condition increased skill performance, the moderate contextual interference improved performance on the transfer test.

However, these studies neither investigated the combined practice nor analyzed movement pattern and parameterization measures. At the beginning of practice, the varied practice leads to unstable movement patterns requiring constant changes of movement parameters (Lai et al., 2000). Under these circumstances, one can expect that constant practice stabilizes the movement pattern and improves the learning of parameter specifications obtained with varied practice. The combined practice was found only in one study investigating sports skills, i.e., table tennis (Marinovic & Freudenheim, 2001). This study compared the combined practice with single constant and random practices, but no effects were found. Furthermore, in this study, there were no specific measures for movement pattern and parameters improvement.

Practice sessions aim to improve technical aspects of sport motor skills, such as spatiotemporal movement patterns and parameters specifications. The former is related to the shape of a motor skill, e.g., the volleyball serve. The latter is related to physical parameters adjustments, e.g., force implemented in the ball to reach a specific area in the court. According to the hierarchical learning view (Summers, 1989), the movement pattern is expected to be learned first and then the parametric adjustments. It is possible to speculate that learning the pattern interferes with the quality of adjustments. Once a skill dimension is learned (i.e., the movement pattern), learners have less variation during execution, which facilitates learning the other dimension, for example, the precision of the serve.

The combined practice (i.e., constant-variable) supports the hierarchy in learning proposal in studies using simple tasks. While the constant practice improved movement structure observed on relative timing error, variable practice improved parameterization observed on total time error (Lai et al., 2001; Shea et al., 2001; Lage et al., 2007). However, analyzing the volleyball serve, a movement structure measure can be the qualitative movement pattern, which compares the performed movement pattern in relation to the expected movement pattern. The parameterization measures (i.e., force and direction adjustments) can be the serve score in relation to a target. Based in these statements, the present work aims to evaluate 1) the effects of combined and random practice in the movement pattern and parameterization improvement of the Japanese volleyball serve and 2) the relationship between the movement pattern and precision of volleyball serve. It is expected that the combination of a constant-variable schedule will lead to learning both movement pattern and parameters.

2. Materials and Methods

Participants — Twenty-two participants self-declared right-handed participated in the experiment. However, those who did not complete all sessions of the acquisition phase were not included in data analysis. Thus, the final sample consisted of 16 males (14.19 ± 1.80 years-old) without previous experience in the specific volleyball motor skill adopted in this experiment, so it was expected for the participants to have reached the mature stage of fundamental movement pattern Gallahue and Ozmum (2001). All participants and their parents were requested to read and sign an informed consent before taking part in the experiment. All the procedures were approved by the Local Ethics Committee at the author's University and aligned with the 1964 Helsinki declaration, amended in 1989.

Task and apparatus — The task of this experiment consisted of performing the Japanese volleyball serve using the dominant arm (Figure 1a). Participants were asked to perform the serve, and the ball should overpass the net and hit a target positioned on the ground on the opposite side of the court and achieve the target bull's-eye. **Ten** Penalty 6.0 volleyball balls (Weight: 260-280g, circumference 65-67cm) was used to perform the serves.

Two instruments were adopted, one to analyze the movement pattern and another to analyze the accuracy of the serve. A higher score represents a higher ability to control the parameterization of the skill, such as force and direction. The movement pattern was analyzed through a checklist for qualitative analysis of volleyball serve (Meira Jr., 2003). The checklist construct validity and reliability was confirmed by Costa, Bandeira, Matos, Cruz and Ugrinowitsch (2018). This checklist consisted of the analysis of the Initial Position, Ball Throwing, Hitting, and Finalization and the total score ranged from 9 to 27 points. Movement pattern was analyzed through the whole skill and by components as well.

A Sony handcam camcorder, model DCR-CVD405, was positioned outside the court 1 m away from the right sideline, at 45° to the server and 1.10 m high from the ground. The pre and post tests were recorded at 30 hz, and the zoom was adjusted so that size of the recorded image was the same in all serve areas. Later, the movement pattern was analyzed in a 15”screen.

The analysis of the parameterization was measured by performance accuracy concerning the target bull's eye, ranging from 2 to 28 points. The serves were performed from three areas marked on the side “A” of the court, 4 m away from the net (Figure 1b). Area 1 (A1) was placed in the center of the volleyball court, 4.5 m from both lateral lines. Areas 2 and 3 were positioned at 1.5 m from the lateral line to the court's left (A2) and right (A3). The serve was carried out closer to the network to minimize the possibility of the results being compromised by participants' physical strength as the work was not performed with adults.

The target was placed on the side "B" of the court, and its center was a distance of 4.5 m away from the net and the sideline of the court. The target has four areas with specific scores. The diameters of the areas are 1.0 m, 2.0 m, 3.0 m, 4.0 m that are scored 28 points, 26 points, 24 points, and 22 points, respectively. When the ball fell out of the target, two lines were delimiting from the serve central area (i.e., A1), touching the edges of the target and remaining outside of the court and one line tangent the end of the target. The score in these areas varied from 2-20 points. The ball that reached the floor in the target direction represented an error on force control and received a higher score than the ball that reached the floor to the right or left of the target. Therefore, the lowest score was 2 points when the ball did not pass the net and was not in the target direction. This instrument was adopted by Fialho et al. (2006) and later improved by Santos-Naves et al. (2014).

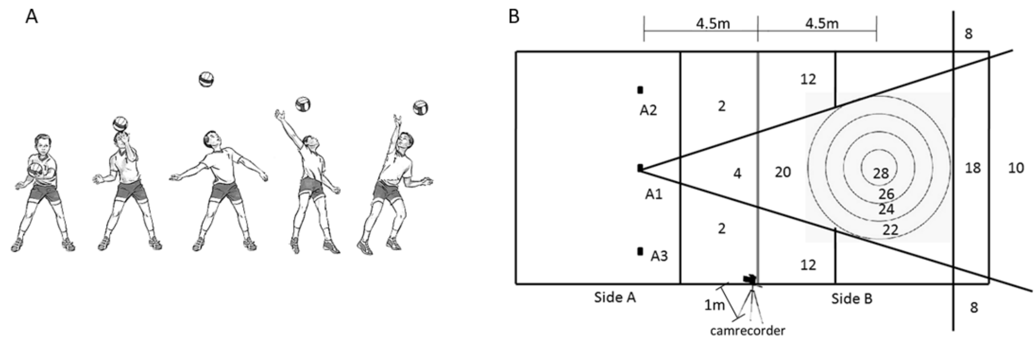

Figure 1. (A) Illustration of sequence of the Japanese volleyball serve. (B) Instrument to the evaluation of the performance of the parameters. A1, A2 and A3 represent serve areas, and the numbers 2 to 28 represent the score of each area the ball touched after serving.

Experimental Design — The participants were arranged into random practice (RPG) and combined practice (CPG) according to parameters performance (i.e., the accuracy of the ball concerning the target bull's eye) obtained in the pretest. This procedure was adopted to ensure that both groups had similar parameters performance for starting the experiment. The participants of RPG performed serves from the three different areas (A1, A2 and A3) in a random order, with the same number of serves from each area. The participants of CPG performed the first half of sessions from A1 (i.e., constant practice), and the second half of sessions were similar to RPG.

The experiment was divided into pretest, acquisition phase and retention test (Figure 2). In the pretest, the participants performed 10 serves from A1, whose movement pattern was recorded for later analysis and parameters performance noted by one researcher. During the acquisition phase, the participants performed 252 trials distributed in two sessions per week for three weeks, with 42 trials in each session. The retention test was performed 48 hours after the last session of the acquisition phase. In the retention test, participants performed 15 serves randomly organized in the three areas. This test was also recorded for analysis of the movement pattern, and one researcher noted parameters performance, the same procedure adopted in the pretest.

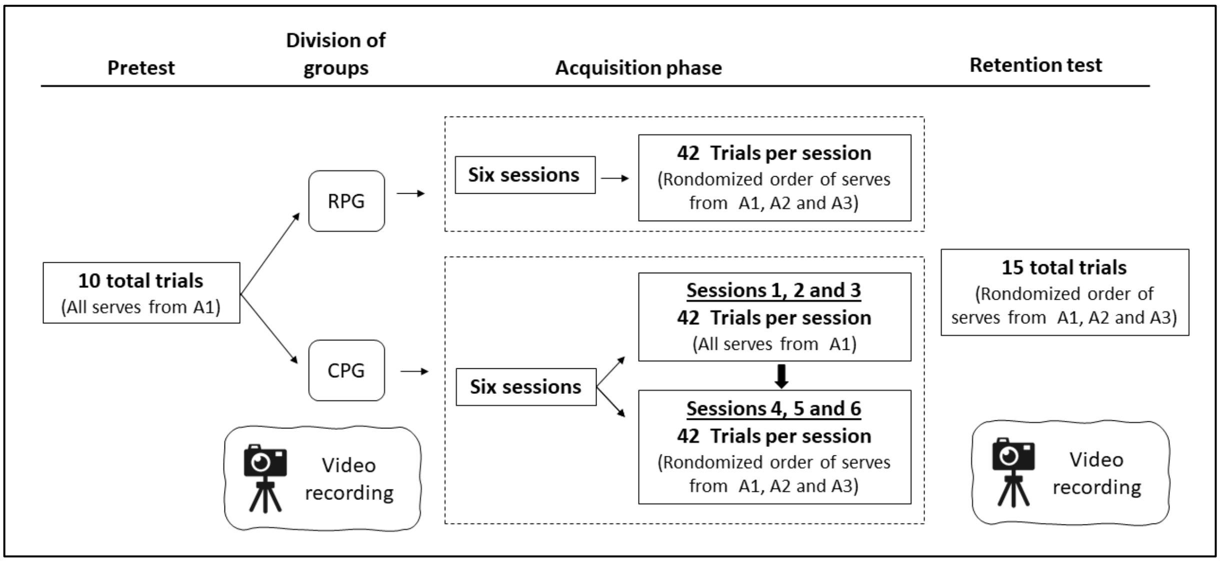

Figure 2. Experimental design.

Procedures — On the first day, standardized instruction was provided before the pretest. Moreover, the participants observed four times a video of an experienced subject performing the Japanese volleyball serve. The video demonstration was used as a reference for the participants to get an idea of the movement pattern to be performed (Malek et al., 2010). After instructions and demonstrations, each participant performed 10 serves. Two days after the pretest, the acquisition phase began, and the same video with the model performing the serve on the first two sessions of the acquisition phase was provided. Then, the participants received instructions following the group in which they were allocated. The RPG received information about the next serve area at the end of each trial. The CPG performed the first three sessions from area 1, and from session fourth to sixth the procedures were the same adopted to RPG. Summarizing, participants performed the pretest on the first day, and two days later, the acquisition phase began with six days of practice. At last, two days after the sixth session of practice, the retention test was performed to analyze the characteristics of the relatively permanent effects of learning (Magill & Anderson, 2017; Schmidt et al., 2019). The experiment lasted four weeks for each participant, but data collection took three months to complete for all participants.

After every trial, the feedback about the location that the ball touched the floor was available, and the intra trials interval was eight seconds (Vieira et al., 2008), similar for both groups. Before data collection, two researchers have run score serve analysis blinded. They observed the same attempts of serve and recorded the scores. The researchers also ran blinded movement pattern analysis through video analysis. Initially, both researchers analyzed the same video separately, and the reliability analysis was carried out. Researchers had reliability higher than 85% in both analyses, which is good for data analysis (Thomas, Nelson, & Silverman, 2011). After this procedure, data collection and the analysis of the other videos followed.

Statistical analysis — Data analysis was performed with the accuracy of both movement pattern and parameters (performance score) by two-way ANOVA (2 groups x 2 blocks) with repeated measures in the second factor. When necessary, the LSD's post hoc was adopted for pairwise comparisons. The movement pattern measure was calculated by the sum of the

mean points of each component. The retention test was performed 48h after the acquisition phase. So, the first three trials were discarded to minimize the warm-up decrement effect (Schmidt & Wrisberg, 1971), characterized by a performance decrement after a long period without practice, which is rapidly restored after practice is resumed.
This procedure was adopted for both, the overall movement pattern analyses involving all components as well as each component separately and for the analysis of the parameters. Moreover, we performed a correlation analysis between parameters performance and components of the movement pattern with Pearson test in the retention test. An alpha level of .05 was used as the threshold for significance. The effect size was also calculated and adopted the qualitative reference values of .01 (small), .06 (moderate) and .14 (large) (Greent & Salkind, 2008). Due to the loss of participants and the experimental situation, when there was a marginal effect (alpha level varying to .06 - .09) and large effect size, the LSD's test was also run.

3. Results

Movement pattern — Figure 3a shows the analysis of the overall movement pattern. It was found a significant interaction between blocks and groups $F(1, 14)=24.58$, $p=.01$, $\eta_p^2=.38$. The post hoc test detected significant improvement of movement pattern from the pretest to the retention test of CPG (p=.005). The RPG showed no significant change in the movement pattern (p>.05). There was neither effect for blocks $F(1,14)=.75$, $p=.20$, $\eta p2=.11$ nor for groups $F(1,14)=.04$, $p=.83$, $\eta p2=.003$. Aiming to identify the movement organization, a separate analysis of each component of the movement pattern was carried out.

The analysis of the first component, i.e., initial position (Figure 3b) showed a significant effect for blocks. It was indicated that the score of this component diminished significantly from pretest to retention test $F(1,14)=6.79$, $p=.02$, $\eta_p^2=.32$. There was neither effect for groups $F(1,14)=.29$, $p=.59$, $\eta_p^2=.02$ nor interaction between blocks and groups $F(1,14)=.40$, $p=.53$, $\eta_p^2=.02$. The analysis of the second component, i.e., the ball throwing component (Figure 3c) indicates a marginal effect on the interaction between groups and blocks $F(1, 14)=2.28$, $p=.08$, $\eta_p^2=.19$. The post hoc detected that CPG improved significantly from pretest to retention test ($p=.01$). There was neither effect for blocks $F(1,14)=2.80$, $p=.11$, $\eta_p^2=.16$ nor for groups $F(1,14)=1.39$, $p=.25$, $\eta_p^2=.09$. The analysis of the third component, i.e., the hitting component (Figure 3d), also indicated a marginal effect on the interaction between groups and blocks $F(1,14)=5.94$, $p=.06$, $\eta_p^2=.21$. The post hoc detected the CPG improved significantly from pretest to retention test ($p=.04$). There was neither effect for blocks $F(1,14)=.96$, $p=.34$, $\eta_p^2=.06$ nor for groups $F(1,14)=.91$, $p=.35$, $\eta_p^2=.06$. The analysis of the fourth component, i.e., finalization (Figure 3e), indicated a significant interaction between groups and blocks $F(1,14)=5.84$, $p=.02$, $\eta_p^2=.29$. The post hoc detected that CPG improved significantly from pretest to retention test ($p=.04$). No other effect was found for blocks $F(1,14)=.31$, $p=.58$, $\eta_p^2=.02$ or group $F(1,14)=.13$, $p=.72$, $\eta_p^2=.009$. A summary of these results is presented in Table 1

Table 1. Descriptive data from CPG and RPG

	Randon Practice Group (n = 7)		Combined Practice Group (n = 9)	
Measure	**pretest**	**retention test**	**pretest**	**retention test**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
Serve score	15.11 ± 2.70	19.69 ± 3.59	15.75 ± 4.62	16.7 ± 4.13
Movement pattern	18.71 ± 1.67	17.74 ± 2.67	17.29 ± 3.69	19.85 ± 4.39

Components of movement pattern				
Initial position	2.71 ± .49	2.40 ± 0.41	2.74 ± .43	2.56 ± .15
Ball throwing	5.70 ± 1.36	5.65 ± 1.60	6.06 ± 1.63	7.06 ± 1.65
Hitting	8.23 ± .65	7.79 ± 2.08	6.58 ± 1.63	7.88 ± 2.38
Finalization	2.16 ± .67	1.92 ± .76	1.93 ± .75	2.35 ± .61

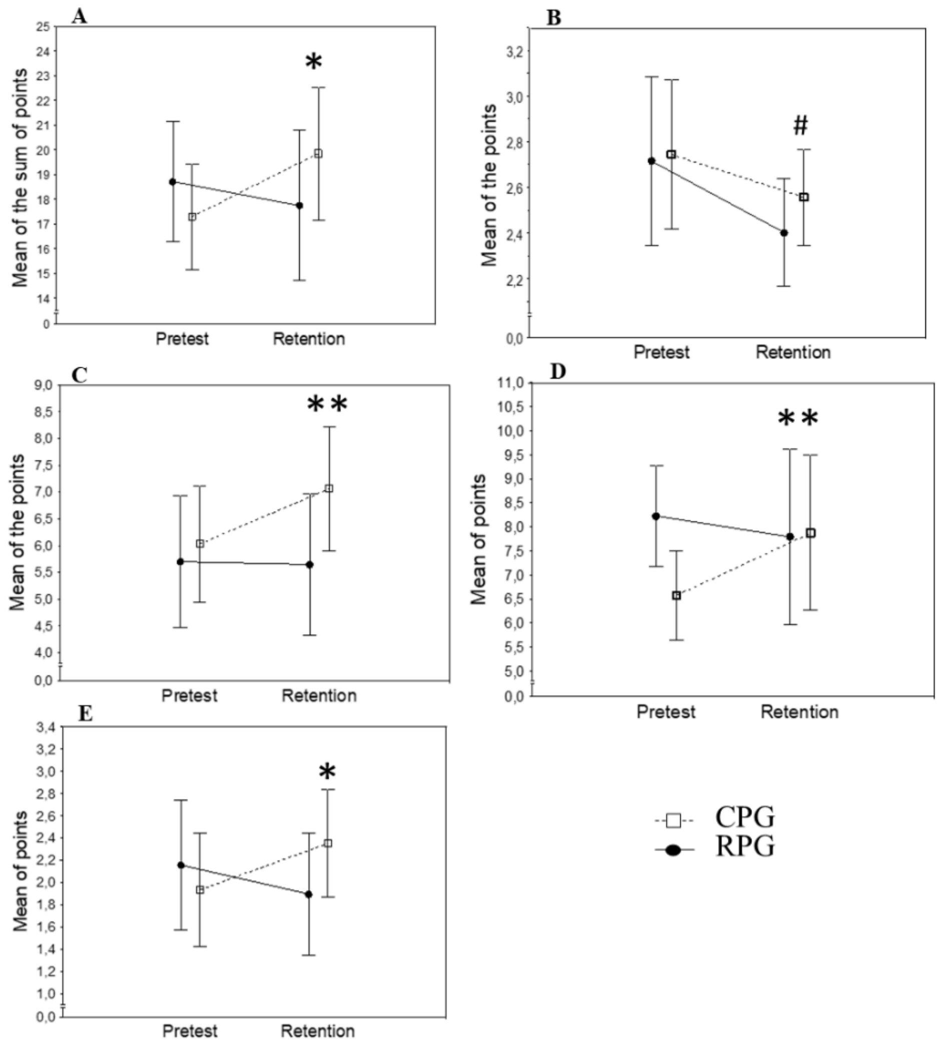

Figure 3. Mean of score from CTG and RTG in the pretest and retention test. A) Sum of scores of the movement pattern; B) Initial position component; C) Ball throwing component; D) Hitting component; and E) Finalization component. Vertical bars represent 95% of confidence interval. # p<.05 Test * p<.05 Interaction ** p=.06-.08 Interaction

Parameterization

Figure 4 shows that parameters performance improved from pretest to retention test $F(1,14)=11.94$, $p=.003$, $\eta_p^2=.46$. Moreover, it showed a significant interaction between blocks and groups $F(1,14)=5.15$, $p=.03$, $\eta_p^2=.26$. The post hoc detected that while the RPG significantly increased parameters accuracy ($p=.001$), the CPG did not change with practice ($p>.05$). There was no effect for groups $F(1,14)=.43$, $p=.51$, $\eta_p^2=.03$.

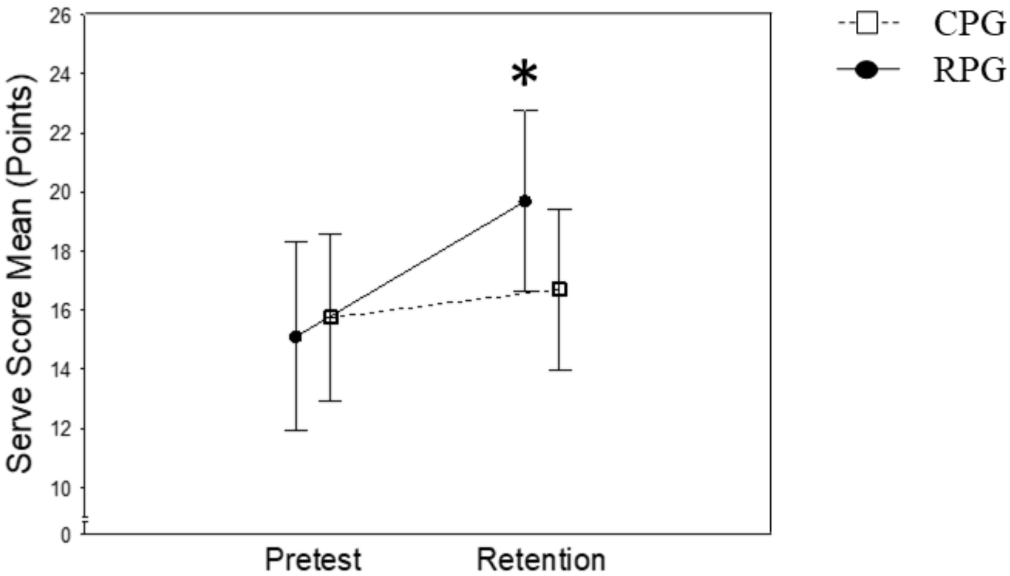

Figure 4. Mean of parameterization from CTG and RTG in the pretest and retention test. Vertical bars represent 95% of confidence interval. * $p<.05$ Interaction

Correlation — Table 2 shows a significant ($p<.05$) high positive correlation ($r=.78$) between the initial position and ball throwing, and significant ($p<.05$) and high positive correlation ($r=.76$) between finalization and parameters performance to RPG. The other variables showed no enough evidence of correlation ($p>.05$). Moreover, Table 1 shows a marginal ($p=.06$) high positive ($r=.63$) correlation between ball throwing and hitting to CPG. The other variables showed no enough evidence of correlation ($p>.05$).

Table 2. Correlation between improvement on the components of movement pattern and performance accuracy on retention test for groups.

	RPG					CPG				
	1	2	3	4	5	1	2	3	4	5
1. Δ Initial position	-	.78*	-.21	-.31	-.24	-	.30	-.18	.14	-.31
2. Δ Ball throwing	.78*	-	-.09	-.51	-.51	.30	-	.63**	-.21	-.52
3. Δ Hitting	-.21	-.09	-	.21	.41	-.18	.63**	-	.07	-.07
4. Δ Finalization	-.31	-.51	.21	-	.76*	.14	-.21	.07	-	-.20
5. Δ Performance Accuracy	-.24	-.51	.41	.76*	-	-.31	-.52	-.07	-.20	-

Note: * $p < .05$ ** $p = .06$ Δ = variation between pretest and retention test

4. Discussion

Prior studies investigated the effectiveness of combined practice, but most of them were developed with simple laboratory tasks. This study investigated the combination of constant-random practice effects and random practice on acquisition of a sports motor skill, the Japanese volleyball serve. The hypothesis was that in combined practice, the constant practice in the early practice stage (i.e., the first half of sessions) would improve movement pattern, and the random practice during the later sessions would improve parameterization. To evaluate the movement pattern and parameterization of the Japanese volleyball serve, we considered the movement pattern and the adjustments on performance accuracy, respectively. The results partially confirm our hypothesis, whereas the combined practice improved the movement pattern but not the parameterization in the retention test.

The movement pattern analysis showed that constant-random practice improved the movement pattern, which was not observed under random practice. This result corroborates predictions that a constant practice schedule favors the movement pattern learning owing to response stability created during practice (Lai & Shea, 1998; Lage et al., 2007; Matos et al., 2017). Constant practice produces greater inter trials stability, which may strengthen the memory process concerning movement patterns. However, in the complex task adopted in this study, which needs control of many degrees of freedom, only the constant practice seems not to have been enough. Although the movement pattern and parameters are governed by independent memory states, they should interact during practice (Shea et al., 2001). Thus, the random practice on the second part of practice, maintaining the movement pattern, contributed to improving the movement pattern, which did not happen without constant practice at the beginning of the acquisition.

The execution of the volleyball serve requires several components; therefore, aiming to identify the way components interact to perform the movement pattern, a detailed analysis by component was run. The analysis of the initial position component showed improvement for both practice conditions. Probably the initial position is the component with lesser demand of practice to improve qualitatively because the performer is still holding the ball. Consequently, it is possible to control the arms and feet position before performing the serve. Following this reasoning, the other three components have a higher probability of improving movement control with practice. In fact, the ball throwing and finishing components improved from pretest to retention test. However, the improvement occurred only in combined practice. Thus, these results allow us to conclude that in the volleyball serve, the components of the movement pattern do not change linearly. Moreover, the components are influenced by practice conditions. Other studies also found no linearity in learning movement patterns in complex sport motor skills (Santos-Naves et al., 2014; Ugrinowitsch et al., 2011), with changes only on ball throwing and hitting.

At this moment, we must highlight that changes in the components of the volleyball serve were observed specifically with combined practice. Thus, although the random practice has improved the performance of volleyball serve of experienced players (Fialho et al., 2006), this type of practice does not improve the movement pattern of participants without experience in the trained sport motor skill. Specifically, learning movement patterns of complex motor skills depends on constant practice, which happens only with combined practice.

Concerning the parameters learning, opposite results were found. Only the random practice improved the parameterization from pretest to retention. This result goes against those found with simple lab tasks (Lai et al., 2000; Lage et al., 2007; Shea et al., 2001). The explanation of our results may be found in the relation between the amount of random practice performed on combined practice and the complexity of the task. Particularly, learning to control many degrees of freedom to perform the movement pattern of the Japanese volleyball serve should be more difficult than learning the relative time of lab tasks. Probably, the more repetitive practice favored the focus of attention on movement pattern, even during combined practice, and the constant changes of the less repetitive practice favored the focus of attention on parameterization, based on constant changes required during random practice.

Moreover, despite the two conditions performing the same amount of practice, the combined practice performed only half of the trials randomly, which was insufficient to improve parameterization (Correa et al., 2006; Santos et al., 2009). This assumption is supported by Shea et al. (1990), when random practice showed better performance improvement with a higher amount of practice (400 trials). However, the smaller amount of practice (50 or 200 trials) was not enough to show the same results. Following this way of thinking, the higher amount of random practice of this study can have conducted to greater cognitive engagement for parameters learning (Lage et al., 2015), resulting in a better distinction between variations (Shea & Zimny, 1983).

Early studies showed a hierarchy on motor learning (Summers, 1989); however, putting it all together, the results offer a new understanding that the learning of movement pattern and parameterization is nonlinear and dissociated but associated with practice conditions. Thus, the combined practice only improves movement patterns, and random practice only improves sports motor skills parameterization.

The relationship between the improvement of movement pattern and parameterization was run through the changes from pretest to retention test of each component from movement pattern changed in parameters of the task. Once more, the results show nonlinearity. The component initial position influences ball throwing, probably because these two components are in sequence, and one depends on the other to perform the skill. However, only the component finalization was related to changes in parameterization during random practice. Thus, random practice improves the ability to make adjustments in parameters of the component finalization, which improves accuracy. In addition, the lower repeatability of random practice improves commitment to the task (Lage et al., 2015), and consequently, the focus on parameterization. This study analyzed movement patterns through qualitative analysis. Although it is very similar to coach analysis, future studies should use kinematic analysis to have more detailed information about movement pattern improvement.

In conclusion, our results support the proposition that movement patterns and parameters are controlled separately (Shea et al., 2001). However, the proposition that combined practice improves movement patterns and parameterization learning is not observed with complex sports skills. The combined practice improves movement patterns, conducting the focus of attention on the components. The random practice improves parameterization, improving commitment to the task. Future studies should try a different amount of random practice in combined condition with sport motor skills. At last, the improvement of parameterization ability is related to the finalization component. New studies about the combination of practice with complex motor skills are necessary to extend the knowledge about practice schedules.

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