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The comparison of Linear and Nonlinear pedagogy on the learning of table tennis forehand stroke

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Abstract
Learning of sport skills is a complex process which is influenced by the individual differences. The purpose of the current research was to compare the Linear pedagogy and the Nonlinear pedagogy on the performance and learning of table tennis forehand stroke. This was a semi-experimental study that was carried out on 22 girls (9 - 11year). Random two groups after pre-test, participated in eight sessions to learn. Then, the immediate retention test was conducted, and after four weeks they took the delayed retention and transfer tests. Although, both groups had progress in accuracy scores also the Nonlinear group in all stages of post-intervention scored better marks, statistically, there was no significant difference between two groups (p>0.05). The results suggested that there are extra ways for learning, by searching and finding a proper movement solution can learn more easily, and recommends instructors to use new methods of learning.

Keywords: Linear pedagogy, Nonlinear pedagogy, motor learning, table tennis forehand stroke

1. Introduction
Acquisition and learning motor skills at early age and childhood is the base of participation in sport activities, retention of health and body fitness during life time and adulthood [1]. Learning a sport skill is a complicated process involves many factors including one's knowledge level, personality-genetic characteristics, social-economic position, previous experiences and learning style and techniques [2]. The main concern of trainers in design of practice is along with considering above-mentioned factors, taking individual differences into account. It is essential, for efficiently learning sport skills, to have a strong theoretical framework in order to confirm practice design instructions; since the way instructor instructs motor skills is very effective [3].
Previous studies suggest that the most prevalent educational approach in the world is traditional approach [4]. Traditionally, instructors have employed repetitive and prescriptive techniques in a way that make learner prepare to acquire skill by demonstration of technique and pattern and verbal instructions, they believe that there is only one motor pattern for doing a task and learning, in this regard seems to be instructor-oriented. The technique and method are called the Linear pedagogy [5, 6].
Traditional practitioners' approach associated with modeling, instructions, optimal movement pattern, and by increase of practice, learning will be enhanced [7]. Traditional methods, in learning a sport skill, focus on technique and practitioner help learner to properly do a skill [8].
In this regard, 'power law' supports the Linear pedagogy and suggests that increasing the amount of practice leads to success and enhance learning; this is a good way for one to be expert in learning and performing a skill [9]. However, there are some critics about this kind of pedagogy. Focusing on repetitively performing the pattern, the Linear pedagogy poorly improves cognitive skills such as decision making and creativity [8]. Moreover, repetition and too much amount of practice take a lot of time [6]. Research evidences in terms of dynamic theory criticize the Linear pedagogy [10]. According to dynamic systems motor behaviors are Nonlinear changes over time, and they believe that Nonlinear pedagogy consider dynamicity and complexity of learning a sport skill [11]. In the new method of teaching, instructor does not specify how the motor behavior should be to achieve the goal of task, he or she rather, while practicing, considers individual differences and environment,

and learner is encouraged to explore different motor patterns that is more compatible with his coordinated structures, and then finds desirable solution for movement [12]. Nonlinear pedagogy by manipulation of task constraints such as instructions, movement rules and equipment (e.g., racquets, balls, and court size), help learner to explore and find practically the easiest way [13, 14]. Chow and his colleagues (2007) were the pioneers who proposed Nonlinear pedagogy to instructors; this type of learning is a part of dynamic systems. Nonlinear pedagogy suggests a structure for pedagogical rules and instructions that can be used in changes of Nonlinear behaviors that is usually observed in learning a motor skill [8]. Nonlinear pedagogy encompasses a combination of display of movement, manipulation of constraints, use of external focus of attention, functional variables, and movement information [15]. Nonlinear pedagogy focuses on the ability to cooperate with momentary changes. Task constraints involve individual and environment that play a major role in exploring and finding functional solutions for learning [16]. In Nonlinear pedagogy and in the main position of movement the goal of motor behavior is emphasized and this goal makes learner ready to, based on change in situation, transfer information from one motor behavior to the other [17].

According to researchers' views variables such as game conditions, techniques, type of stroke and so on bring about many learning opportunities, while Linear pedagogy researchers believe that changes in these factors' learner cannot match and adopt what he has practiced with game condition. As a result, Nonlinear pedagogy is suggested to achieve a dynamic and more effective learning [18]. Chow *et al*., (2014) claim that to acquire motor skills, Nonlinear pedagogy, in comparison to traditional approach, enables learner with more versatile movement solutions**.** Chow and Atencio in 2014 underpinned the role of teachers in Nonlinear pedagogy through manipulation of constraints in order to facilitate behavior, more exploration by learner to find a motor solution, create a suitable condition for motor variability that leads to self-organization at a high level in different areas of learning [19]. Moreover, despite Linear pedagogy, the Nonlinear pedagogy focuses on goal and result, and since the external focus of attention is used, intelligently process of information in acquisition of a skill is reduced [20].

A better coordinated movement for learner is provided by several movement solutions, and when the goal of a task is determined for individual, he would try different ways to solve the problem [21]. In this way, Nonlinear pedagogy approach suggests instructors to design creative drills so that learner becomes skillful in dynamic environment [8].

Previous studies indicate that individual differences play a part in acquisition and motor control while a similar task is proposed. Nonlinear pedagogy considers individual differences while designing practice and when the focus is in drills that have interaction between task constrains, individual, and environment [20].

According to Bernstein's theory (1967) muscle-joint connections of learner, as coordinated structures, while performing a movement task and coordinated for every special condition to correspond with different elements of motor parts to perform the task in the best way. Due to complex neural system and a wide range of solutions as for achieving a common goal, one develops his knowledge and life experiences by exploring and finding signs; Nonlinear pedagogy is a proper hotbed for individual to learn more effectively. Learning through Nonlinear method gives more opportunities by providing investigative conditions so that learner would find more coordinated patterns against current conditions [22, 23]. The results of researches showed that people, based on their individual differences, make use of different and distinct coordinated patterns to achieve task goals, the new education approach cater for manifestation of these coordinated patterns and focuses on dynamic learning in learner [24].

Despite the traditional education approach that relies only on one motor pattern, the Nonlinear pedagogy provides a proper theoretical framework for instructor to consider individual differences and environment while designing an exercise [25]. Researchers like Williams (2005) and Chow (2007) believe that, unlike what traditional trainers believe, there are more than one motor criterion pattern as to achieve a common goal in which every individual by exploration can figure out his proper movement solution. Recent studies indicate that many could have reached an effective coordinated pattern and in performing tennis forehand stroke have achieved task's goal and high scores [20]. Davids (2003) claimed that traditional methods in transferring skill to reality have many limitations. Continuing his researches with the aim to design learning in dynamic Nonlinear systems in 2012, he proposed theoretical bases for learning through dynamic motor system. He also stressed on using new learning methods due to a wide range of practices that assimilate conditions of practice environment with real game competitions. Though, this kind of pedagogy also has its own limitations. Make a self-organized movement solution in each learner depend demand individual interaction with task constraints, and a unique environment that the instructor applies in practice according to learner's progress. This method, due to differences in individuals might take a long intervention time, as a result, in case that there are a lot of learners and it is hard to make it applicable for school's rules require more investigations [8]. On the other hand, according to previous studies too attention of Nonlinear pedagogy to the result of movement, in comparison to technique and form of movement, bring a situation in which individuals do not learn correct pattern and technique [10]. There exist some questions in this regard, such as does the lack of learning the main pattern of a skill create problem for an athlete? Does the focus on the pattern and focus goal while learning a skill should occur in two different timespans? And does the focus on these two matters is depended on skill level of learner? These ambiguities stress the necessity of further studies in order to confirm the current results [26, 27]. Chow *et al*. (2013) proposed evidences, challenges, and concepts of Nonlinear pedagogy and emphasized that acquisition of motor skills supports Nonlinear pedagogy, and task constraints, individual, and environment are three fundamental elements of learning. Even though, they suggested that this information should be applied practically for instructor's job in future studies. In this regard we are faced with this question that is motor learning enhanced by using Nonlinear pedagogy instructions, in comparison to the Linear pedagogy? Or a combination of both is more effective way? Accordingly, the purpose of this research is to study the Linear pedagogy and the Nonlinear pedagogy in learning table tennis forehand stroke so that to find more detailed information on the Linear and the Nonlinear pedagogy in field conditions.

2. Materials and methods

2.1 Participants

Participants were 22 girls (using G Power software and effect size of 0.33 by significance level of $p>0.05$) right-handed [10]. They were randomly assigned into Linear pedagogy group

(average age: 10±1 yrs.) and Nonlinear pedagogy group (average age: 10±1.5 yrs.) (n=11). All participants, according to health case were in a good physical condition. They were novice at table tennis and had no previous formal learning. Moreover, before starting the study the informed parental consent was obtained from parents. (Appendix 1)

2.2 Task
The research task was table tennis forehand stroke that each group learned it according to their special condition. The task test includes the accuracy of table tennis forehand of Liao and Masters (2001). The aim of task was stroke of forehand table tennis and landing the ball in predetermined areas and getting the best accuracy score.

2.3 Procedures
This study included five stages: pretest, acquisition, immediate retention, delayed retention and transfer stages (four weeks later).

At the first, participants participated in three sessions of 30 minutes to be familiar with the ball and the racket. These sessions embodied controlling stroke, hit by the side of the paddle made with the palm of the hand in standing position and in motion in order to take control of the ball. Then, a training session was provided with displaying a movie for both groups in which the form of doing the skill by a professional player was displayed for participants. In addition, learners were informed on task constraints including rules of forehand stroke and task errors. Then they participated in pre-test. The pre-test, immediate retention, delayed retention was all the same in the way that after five-minute warm-up, they did two five-trial blocks of the task which was the accuracy test of table tennis forehand stroke. In these stages, the ball was sent to participants by instructor through a simple no spin service to the right side of them and they did a forehand drive. In the transfer test stage, the directions of determined goals on the table were changed. The accuracy of table tennis forehand stroke was measured by Liao &Masters test (2001) [29]. The right corner of the table was divided into five areas, each stroke was scored according to where it landed, from the first area to the fifth area, if went out of the table it scored 0 point. At last, the average point of 10 strokes was put as the accuracy score. Landing points were spotted by camera and to score precisely by examiner (Figure 1).

2.4 Practice Protocol
after took the pre-test, participants engaged in eight 15-minute sessions, three sessions per week in which they made 80 trails per session so that to learn table tennis forehand stroke in two ways of Linear and Nonlinear. Practice protocol, Linear and Nonlinear interventions of drills were confirmed and designed by expert's viewpoint and related articles [10].

Drills of Nonlinear group were designed using its instructions that include manipulation of constraints and set a specific boundary for learner so that to search and explore proper movement solution [19]. In order to do so, net height, targeted areas, how to achieve the goal of task and also the verbal instructions focusing on the goal of the task were considered in design of Nonlinear drills. Verbal instructions were such as: "hit the ball to make a rainbow arc above the net, or hit to the side of the ball so it lands on determined area, or move your hand toward the target by ball." [10]. Individual differences were considered in Bernstein's dynamic systems theory and Nonlinear pedagogy, this indicated that blacksmiths did not act the same while hitting by the hammer, he argued that muscular-joint connections of learners, defined as coordinated structures, in the time of doing the movement task and for any special condition, coordinated together in the way to be perfectly compatible with other parts of movement and perform the task in the best way [28]. Participants of Nonlinear pedagogy group did the training changes in 10 trails per session and carried on for the next change during the following attempts.

On the other hand, there was the Linear pedagogy in which all participants used one single pattern and one way to do the task. According to the focus of this pedagogy that is on form and the way of doing technique, they followed traditional and educational instructions of table tennis forehand stroke based on prescriptive instructions and repetition of consecutive practices under the supervision of the instructor, and by these repetitive practices learnt the skill. Every session of Linear pedagogy includes: 1. Preparation and shadow practices by focusing on the correct way of holding racket and doing forehand stroke without the ball, 2. The stage before stroke or hit by emphasizing on where to stand on the table and the best position for stroking forehand, 3. The stage of stroke by emphasizing on how to hit the ball, the angle of hand, feet, and waist while implementing technique, 4. The next stage followed the stroke by considering pattern of forehand movement [29].

2.5 Statistical Methods
Shapiro-Wilk test was used to examine data normalization and Levene test was used for homogeneity of variances. The results of these pre-assumptions were confirmed ($p>0.05$). Moreover, a mixed and repeated measures analysis of variance (ANOVA) was used. Control of differences distribution was done by Bonferroni post hoc test. The significance level was considered $p\leq0.05$ for all tests and all these analyses were carried out by SPSS 22 software.

3. Results & Discussion
3.1 Results
According to the data test, the condition is fitted to be used in parametric tests (Table 1). The results showed that there was statistical difference between stages of tests ($F=10.14$, $\eta^2=0.36$, $p=0.001$); but there was no difference between groups ($F=0.182$, $p=0.67$, $\eta^2=0.01$). The results of Bonferroni post hoc test in two groups of Linear pedagogy and Nonlinear pedagogy demonstrated a growing trend; the average scores of Nonlinear group in the immediate and delayed retentions were higher than the other group, and the Linear pedagogy group showed a better performance only in pre-test, that the difference was not significant (Figure 2).

3.2 Discussion
The main aim of this research was to compare the Linear pedagogy and Nonlinear pedagogy on the performance and learning of table tennis forehand stroke. The results of this research, along with previous studies, showed that both Linear and Nonlinear pedagogy made a considerable progress but none showed a significant superiority over the other one in accuracy scores of forehand strokes. After an eight-session practice both Linear and Nonlinear pedagogy improved their performance. Achieving high scores in accuracy participants, Nonlinear pedagogy used different patterns to attain the same results [16]. This means, by far, that the Nonlinear pedagogy could have helped individuals in achieving effective results and in reaching the task's objectives. Lack of significant difference between Linear pedagogy and Nonlinear pedagogy

groups reveals that there may be a need for more practice and repetition in Linear pedagogy group. The results of current research are consistent with studies of Lee *et al*. (2014), and Davids (2008) [4, 7]. In addition, in study of Lee (2014) the tennis forehand stroke taught using Nonlinear pedagogy and through manipulation of constraints, and although some kinds of variability were observed in performance of participants, they reached the objectives of task as Linear pedagogies did [10]. No significant difference, statistically, between two Linear and Nonlinear pedagogy groups in the current study maybe due to short-time intervention of Nonlinear pedagogy group. In long term it might be more effective, and children could explore more to find more complete and designed movement solution. On the other hand, the Linear pedagogy group due to emphasize and focus on pattern, couldn't get better scores and, thus, there were few differences between two groups' scores.

Notwithstanding the fact that, statistically, the Nonlinear pedagogy group finished with not better scores than the Linear pedagogy group, but given the fact that in pretest, they recorded better accuracy scores than the Linear pedagogy group. Thus, the results showed that it is not necessary for learners to imitate the pattern and model to achieve the goal and succeed, as the Nonlinear pedagogy group by encouraging learner to explore and have variability were more successful [10].

Fatigue and lack of motivation in the Linear pedagogy group might bring lower marks. This result is consistent with Renshaw (2012) that emphasized the role of new learning methods on the intrinsic motivation of learners [24].

Higher scores of the Nonlinear pedagogy group in the immediate and delayed retention stages draw attention to the variability of different ways in order to get a common goal. Studies of ecological theories and dynamic systems on learning and performing sport skills have indicated that there is a relationship between accuracy in performance and functional variability, and this variability of using main constraints to achieve a proper movement pattern for each person plays an important role to help learner to be compatible with environment changes and task's different needs during practice and play [19].

Comparison of average groups suggested a growing trend; but averages of both groups reduced in transfer stage. However, the fall in the Nonlinear pedagogy group was less severe; they due to ability to adapt with task's constraints and different conditions of test could have better scores in the transfer stage. Although, in terms of statics, there was no significant difference between the Linear pedagogy and the Nonlinear pedagogy, the Nonlinear pedagogy group, having exploratory opportunities, due to different changes in drills and based on instructions of this group that are completely different from the traditional method, showed a better performance. The Linear pedagogy group, on the other hand and despite other stages, scored the lowest marks in the transfer test, and this shows one of the disadvantages of the traditional method in which transfer to different conditions or real game [11, 12].

Within-group means indicated that changes made by learning among two groups through table tennis forehand stroke practices; by using data analysis improvements were observed during test stages and scores of delayed retentions by greatest average has a significant difference with pre-test.

Instructions of the Nonlinear pedagogy is capable of considering individual differences in design of practice; in this research participants were not bound to a pre-determined movement pattern, rather they could search and explore suitable movement solution, despite limitations. In this regard, the Nonlinear pedagogy approach by considering individual differences and a wide range of movement solutions can be compatible with dynamic environment [10, 30].

From a purely practical point of view, if learners didn't imitate exactly the correct movement pattern, instructors do not need to be worried about, but they should focus on instructions that create a pattern which is tailored for every single person, use of coupled information of movement, result of movement, functional variability of movement, and manipulation of task constraints so that learner by searching and exploring can perform an effective movement solution [12]. Even though, there seems to be some concerns about the Nonlinear pedagogy such as "Is learning through Nonlinear pedagogy a time-saving method?" or "are the instructors educated enough to teach in this way?" or "is it really effective?" [14]. This study proposed some empirical evidences that the Nonlinear pedagogy is effective and worth following.

3.1 Tables and Figures

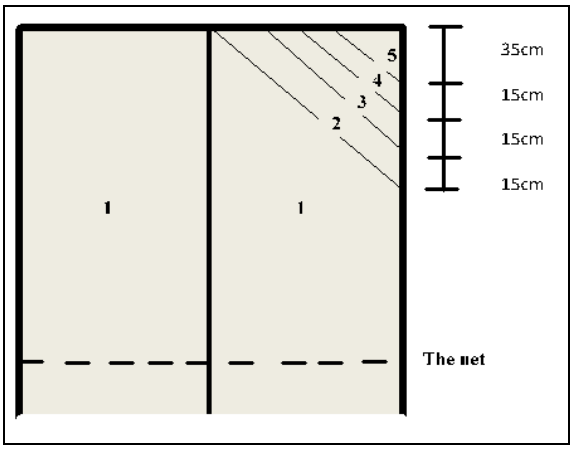

Fig 1: Accuracy test of table tennis forehand stroke (Liao & Masters, 2001)

Table 1: The results of Shapiro-Wilk table in order to examine normalization

Stages	Learning method	Test statistics	Significance level
Pretest	Linear	0.85	0.07
	Nonlinear	0.89	0.18
Immediate retention	Linear	0.92	0.37
	Nonlinear	0.9	0.25
Delayed retention	Linear	0.93	0.53
	Nonlinear	0.86	0.8
Transfer	Linear	0.9	0.22
	Nonlinear	0.89	0.18

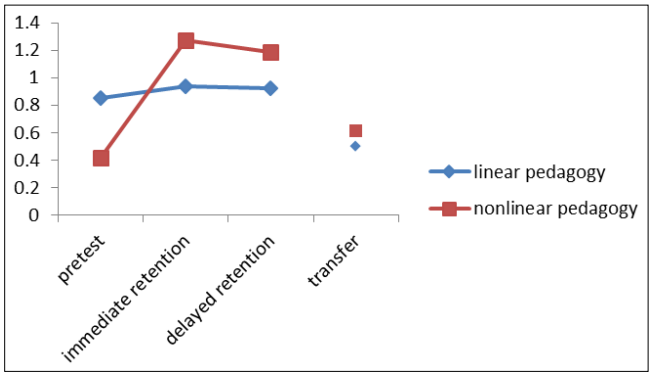

Fig 2: Average scores of two groups in all of the stages

4. Conclusion

This research, by studying the Nonlinear pedagogy, sought to introduce new method of learning and create a more effective learning, and also comparing it with traditional methods. In general, the results of the research showed that the Nonlinear pedagogy has an impact on performance and learning, but there was no significant difference between the Linear and the Nonlinear pedagogy. However, more studies and evidences are essential in this regard. Further studies on learning methods such as the Nonlinear pedagogy are needed to put this knowledge into practice.

Motor learning or acquisition of coordination is a process of exploration to achieve a sustainable, coordinated and functional pattern; according to this concept, it seems that the process of exploration is a turning point, in face of complicated human being with abundant degrees of freedom. Certainly, people with different movement experiences who are capable of using degrees of freedom should be directed in the best way so that to give a better meaning to the process of exploration. It seems that the Nonlinear pedagogy derived from ecological viewpoint by providing movement affordances through manipulation of constraints, especially task constraints, paves the way for direct perception of movement pattern and makes it possible for exploration of movement solutions.

Appendix

Appendix 1: Parental Consent Form

School Instructor:
Purpose of the study:
The purpose of this study is to find ways to facilitate learning sport skills.
Procedures to be followed:

1. There are no risks associated with research.
2. Your child will not receive any compensation for her participation in this research.

If you would like for your child to participate, please sign your name below.

I give permission for my child …… to participate in the sport research study.

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Disclosure statement

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