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Original Research

Comparison of the Effect of Linear and Nonlinear Pedagogy on Risk Factors of ACL Injury: Emphasis on Kinetic Variables in Basketball Landing

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ABSTRACT

In this study, the effect of linear and non-linear training methods on kinetic variables in basketball landing was investigated, and changes in force and moment from pre-test to post-test were evaluated. The present study was a quasi-experimental experiment, and clinical research method. Participants were 24 students who were selected from Kharazmi University by available methods. They practiced basketball skills in two groups of linear and non-linear for 16 sessions. In the linear method, the presentation of patterns and feedback was used for training, and in the non-linear method, the manipulation of constraints was used. The variables measured included VGRF, knee flexion/extension moment, knee valgus moment, and ankle dorsiflexion moment. The results of the covariance analysis showed that the nonlinear method has a significantly better effect on all kinetic variables compared to the linear method ($p<0.05$). The results of this study consider nonlinear methods as an effective strategy in clinical settings, and emphasize on the role of constraint manipulation in practice and learning environments, and highlight that nonlinear methods, with focusing on exploration and search for solutions, to prevent ACL injuries efficiently by affecting kinetic variables.

Keywords: Training method, Linear, Nonlinear, Kinetic variables

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INTRODUCTION

The knee joint is one of the largest joints in the body, and its ligaments are frequently damaged in various sports movements. The most common knee ligament injury is to the anterior cruciate ligament (ACL), which originates in about 70% from non-contact actions or situations such as jumping, spinning, and landing in sports such as basketball [1- 3]. ACL defects and injuries have a severe effect on the static and dynamic stability of the knee and lower limb. This defect causes effective sensory feedback in the injured knee, which can lead to decreased function, balance, and destruction of the knee joint [4]. In addition to the high cost of annual treatment, this injury causes loss of sports participation and even the loss of the sports season, as well as causes secondary injuries such as osteoarthritis (more than 10-fold increase), meniscus rupture, and psychological problems in the person [2]. Therefore, it is important to try ACL injury reduction or help prevent it.

One way to reduce ACL injury is to use a motor learning strategy. In this regard, ACL injuries are lower in athletes who are satisfied with exercising and training compared to those who are not [5]. The use of motor learning strategies to prevent ACL injury has been considered by researchers in recent years. For example, studies have found that the use of explicit instructions and feedback in landing movement is effective in reducing ACL injury [6]. It has also been shown that motor skills can be learned by focusing on internal (IF) or external (EF) attention to help prevent injury [7]. In this regard, Benjamin et al (2015) consider learning-based training methods that are accompanied by feedback to be appropriate for preventing ACL damage in basketball players' cutting movements [8]. However, it is not entirely clear whether these strategies are the best way to prevent injury [9], because in motor learning, there are newer training methods that are useful in different dimensions of motor performance [10], and it is claimed to be useful to prevent injury.

New strategies of training in motor learning are linear and non-linear methods. The linear method originates from a cognitive point of view. In this view, it is assumed that learning is the result of practicing the ideal model, and variability in practice dissolves the learning path. [11]. In this approach, because the emphasis is on providing an optimal pattern, its training methods are also linear, i.e. the person tries to automate by repeating the proposed movement pattern, and the instructor tries to strengthen the person's learning by providing feedback during the learning process and feedback is reduced with person progression [11]. In contrast to the linear method, the non-linear method is derived from the ecological dynamics. In this view, it is argued that learning is the result of a person's perception of the environment [10]. In other word, in nonlinear method, person achieves growth and learning by being in the environment and solving the challenges ahead [10]. Therefore, this approach finds variability useful in practice and states that no movement in the real environment is similar and that each movement will have its unique response in proportion to the interaction of constraints. Therefore, the more a person practices in an exploratory and challenging environment commensurate with his unique characteristics, the more degrees of freedom are exploited in his nervous system, and this leads to appropriate movements in different environments and prevents damage from dictated movements [12]. In this method, learning is created by encouraging the individual to solve the challenges posed by constraints [10]. There is also no ideal model for all people, but the coach leads the individual to learn and develop a specific skill by manipulating of constraints according to his/her unique physical characteristics [10]. Proponents of this training method claim; placing a person in an exploratory environment increases his motivation to discover a movement pattern tailored to his unique physical characteristics. Therefore, this method is enjoyable and by preventing the additional exercise pressures on the person, it prevents his/her injury and pushes the person to continue the effort in the direction of the goal [10].

In reviewing the background of comparing the linear and nonlinear methods, studies show that the nonlinear method's effect on various variables is better than the linear method [13-16]. In the field of ACL injury prevention, Mohammadi Orangi et al (2021) showed that the nonlinear method is more effective than the linear method for preventing ACL injury [17]. In this study, kinetic and kinematic variables were evaluated as effective factors in preventing ACL injury before and after training and in the cutting task. In preventing ACL injury, the method that leads to more flexion at the articular or reduces the force on the ground is usually considered an effective method because, with more flexion, the force exerted by muscles becomes

neutral. However, study of Mohammadi Orangi et al (2021) was the only study available in this field, and based on the specific suggestion of its authors, the continuation of such a study for a task such as landing provides acceptable results. In the study of Dehghani, Mohammadi Orangi, and Shahriarpour (2021), this issue was investigated on the kinematic variables in basketball and the results confirmed the effectiveness of the nonlinear method [17]. However, information on kinetic variables is limited. Therefore, this study aimed to compare the effect of linear and nonlinear methods on kinetic variables in basketball landing to introduce an effective solution to prevent ACL injury.

MATERIAL AND METHODS

Participants

The strategy of the present study is a quasi-experimental experiment and clinical research method. The statistical population of the study consisted of all students of the Kharazmi University of Tehran and the statistical sample for each of the educational groups was 12 (24 people in total) boys who were selected by convenience sampling method. They were all college students, ranging in age from 18 to 32, and all of them were beginners in basketball. Criteria for being a beginner included: 1. asking the participant in the personal information questionnaire, 2. not passing the basketball unit based on the printout of the transcripts [17].

Inclusion criteria included: 1. the health of the participants at the time of the tests, 2. No injury to the lower extremities and the exclusion criteria included and, 3. Lack of cooperation during the intervention or test. Also, none of the participants had a history of lower limb surgery or medical or neurological problems. This study included a pretest that measured the kinetic variables in one of the laboratories in Tehran, the intervention consisted of 16 training sessions and a post-test similar to the pretest. Initially, the proposal was approved by the Faculty of Physical Education of Tabriz University and the necessary permits were obtained. The code of ethics for this work was also received from Mohaghegh Ardabil University.

Instruments and Examinations

Kinetic data were collected in the laboratory by the force plate. To collect this information, a step was placed in front of the person and the person was asked to land with their superior foot. That is, the person was descending from the steppe with one foot. The step height was the same for all participants and each person performed three landing movements and its average score was considered as the person's score. The instructions given to the participants were first verbal and then executed by the researcher, and each person was given a chance to practice the task once.

To obtain the information on the attached markers (marking was the same with previous studies such as, [17]) they recorded information and the pre-test and post-test were comparable. The data were filtered at a frequency of 50 Hz (such as [17]) and also analyzed by MATLAB software, and a statistical method was performed on them in SPSS. The variables measured in this study included VGRF, knee flexion/extension moment, knee valgus moment, and ankle dorsiflexion moment. Decreasing the VGRF and increasing other variables are considered factors to prevent ACL injuries [8, 17].

To conduct this research, 24 novice male students in basketball at Kharazmi University were selected as available and after explaining the research objectives in the next step, the participants were randomly divided into two groups of linear and nonlinear exercises. Participants then performed a pre-test on dependent variables. For this purpose, 21 reflective markers with a diameter of 14 mm were installed according to the Vicon Plug-in-Gait marker set and with markers on the chest, clavicle, C7, and T10 on the left and right [17].

Everyone wore sports shorts and sweatshirts [17]. Then, to determine the superior and non-superior foot of each subject, a ball was placed in front of them and they were asked to shoot it with their foot as far as possible. The foot with which the subject shoots the ball is considered the superior foot and the foot on which he preferred to stand and support the striker's foot is considered his non-superior foot and the results were recorded. The participants then descended from the steppe with their superior feet. These steps were

the same in the pre and post-test. In this study, participants practiced two sessions (16 sessions) per week for two months and 115-90 minutes per session [18].
Table 1 shows the differences between linear and nonlinear training methods and has been emphasized in previous studies [13, 17]. In this study, interventions commensurate with these differences were developed. However, in general, in the linear training method, each of the basketball skills was practiced separately and eventually became a game. In this way, the instructor introduced the ideal pattern to the performers and asked them to repeat this pattern. This is because recent studies consider visual feedback to be more appropriate than verbal feedback in introducing a pattern [8]. In this training method, partial feedback was given for each action. For example, in passing, it was said how far the ball should be from the chest and how the hand should be placed. In this method, the instructor gave feedback on all the items that should have been considered in the ideal pattern, and before starting, he showed the ideal model to the participants [12].
In the nonlinear training method, no ideal pattern was given to the participants. Instead of partial feedback, general instruction was given on the individual's performance. For example, in the passing task, in addition to practicing different distances, balls of different sizes and weights were given to the learner to select and practice according to their physical characteristics. The environment was designed to achieve training goals tailored to the individual's characteristics [19, 20]. To do this, before training, physical characteristics such as height, weight, and other characteristics affecting the design of the exercise were measured. Therefore, to achieve the training goals, the environment was designed to fit the physical characteristics of each person. It was thought that in this training method, the individual will find a dominant pattern tailored to his or her characteristics [12]. Finally, the post-test is evaluated similarly to the pre-test in all variables. Both training methods have been used in recent research.

Table 1. Overview Practical differences between linear and nonlinear training methods

Method / Rules	Linear	Nonlinear
Goal	The goal is clear and the subject must reach it	The goal is clear and the subject must reach it
Pattern	There is an ideal pattern that the subject should follow	There is no optimal pattern
Description	A description of how it works and is done is allowed and even displayed	There is no description of how the operation is performed, but the function method may be said.
Repetition	There is repetition	There is repetition
Variability	Variability is based on changing exercise intervals	Variability is done by manipulating constraints and adding constraints
Feedback	Feedback is given	No feedback
Instruction	Instructions to achieve the ideal pattern	Instructions are given to set the boundary, for example, it is said that you cannot go beyond a certain line

Statistical Analysis

Data were analyzed using SPSS 24 software. Kolmogorov-Smirnov test at the level of 0.05 was used to check the normality of the data. An Independent t-test was used to compare the demographic information of the two groups and analyze the effect of exercise on dependent variables and to determine which group is better, analysis of covariance was used at a significance level of 0.05.

RESULTS

The results of the Kolmogorov-Smirnov test showed that the data were normal ($p > 0.05$). The demographic information of the participants is given in Table 2. As it is clear, there is no significant difference between the two groups in demographic information.

Table 2. Demographic characteristics of the participants

Variables	Linear Group Numbers:12 M± SD	Nonlinear Group Numbers:12 M± SD	p
Age (year)	26.241± 2.504	28.197± 4.35	0.96
Weight(kg)	79.379±2.364	79.395± 4.396	0.81
Height (cm)	181.501± 2.588	180.916± 4.921	0.12

Before analyzing the data, the presuppositions related to the analysis of the covariance test were checked and confirmed. As shown in Table 3, the results showed that there is a significant difference between the two training groups for all variables ($p < 0.05$). Examining the mean between the groups in the post-test, which is shown in Figures 1 and 2, were find that the nonlinear group in all variables was significantly better than the linear group. VGRF decreased and knee flexion/extension moment, knee valgus moment (negative), and ankle dorsiflexion moment increased. This issue was more in the non-linear group than the linear group.

Table 3: Results of covariance analysis for kinetic variables

	FD	F	P	ETA
VGRF	1(22)	177.73	0.04	0.99
Knee flexion and extension moment	1(22)	8.67	0.042	0.68
knee Valgus moment	1(22)	14.45	0.01	0.78
Ankle Dorsiflexion moment	1(22)	31.3	0.00	0.70

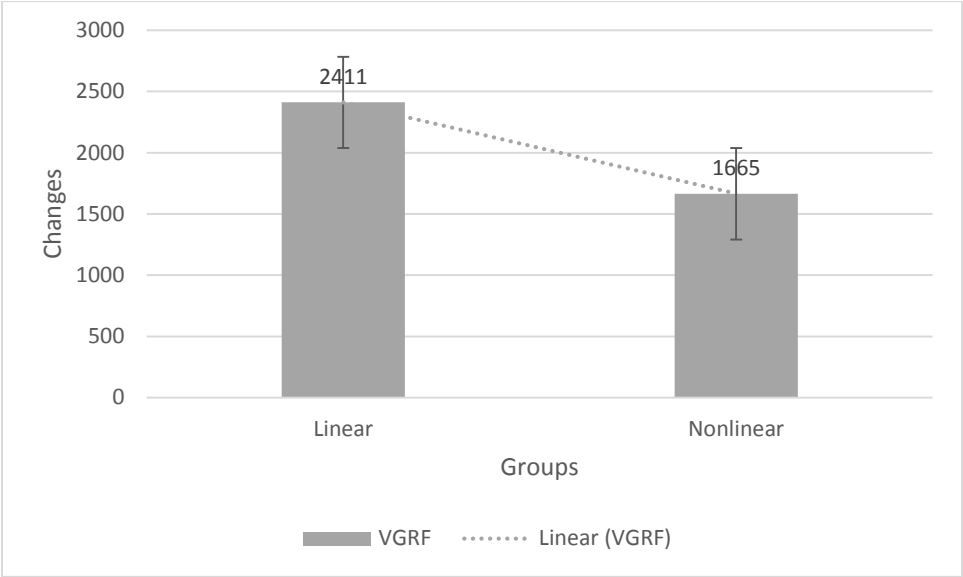

Figure 1. Difference between linear and nonlinear methods in post-test for VGRF variable

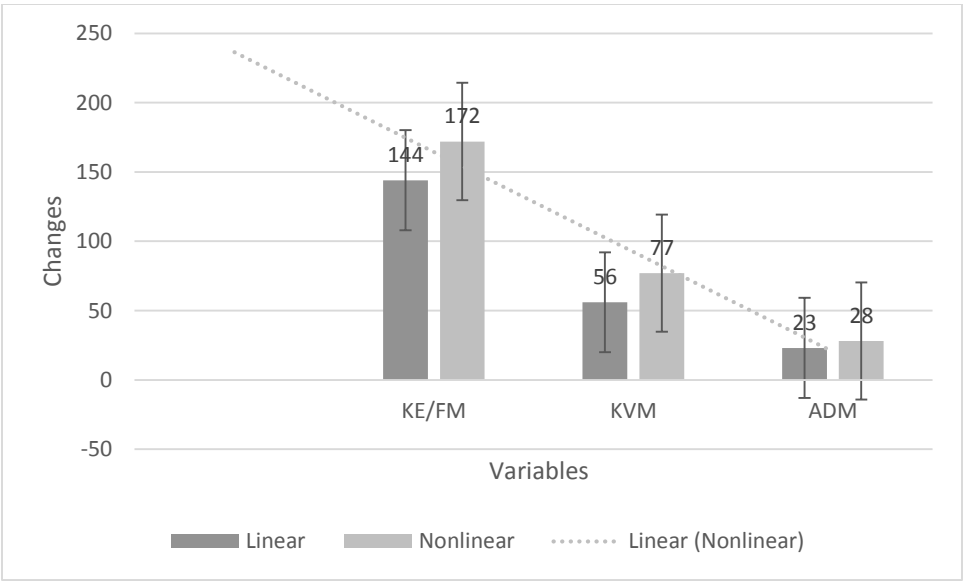

Figure 2. Difference between linear and nonlinear methods in post-test for extension/flexion torque (KE / FM), knee valgus torque (negetive) (KVM), and ankle dorsiflexion (ADM)

DISCUSSION

This study aimed to compare the effect of linear and nonlinear methods on kinetic variables in the landing task of beginner basketball players. In general, the results showed that in all the studied variables, the nonlinear method is significantly better than the linear method; VGRF decreased and knee flexion/extension moment, knee valgus moment (negative), and ankle dorsiflexion moment increased.

Although limited studies have been conducted in this area; the results of the present study are consistent with the study of Mohammadi Orangi et al. (2021) [17]. In the mentioned study, the effect of linear and nonlinear methods on kinetic and kinematic variables was investigated and the results showed that the nonlinear method is better than the linear method to the prevention of ACL injuries.

In discussing why more flexion prevents injury, it should be noted that muscles are less involved when the joint is close to zero or 180 degrees. In this case, the tendons and ligaments withstand the resulting force, and this force may be detrimental to ligaments such as the ACL in movements such as landing. But when there is a lot of flexions, the force is distributed between the opposite and positive muscles and the ligament is faced with the least force, and because the force is distributed in the muscles around the ligament, less force is applied to the ground [18-23].

In discussing why the nonlinear method is effective in preventing ACL injury, it should be noted that in 2013, Ranganet and Newell examined this issue from a variability perspective [24]. They believe that variability in practice helps the individual to learn all possible ways to solve a motor problem [24]. Contrary to popular belief that variability is detrimental to performance learning; variability is not only detrimental to performance but also functional [24]. Learning multiple ways to act means taking advantage of greater degrees of freedom, and this helps one to choose the way with the least energy, cost, and risk (24). In the linear method, the pattern is practiced, but in the nonlinear method, an individual-specific pattern is discovered [24]. Therefore, it is natural that the degrees of freedom released or exploited at a practice time for nonlinear methods are not equal to the linear method, and the nonlinear group shows fewer risks associated with injury [24], which is supported by the results of the present study.

The present results can also be explained with Bernstein's (1967) view. Bernstein (1967) stated that no two movements are performed the same in the real environment and sports. So, providing feedback and pattern to achieve an ideal pattern was criticized, and manipulation of constraints in practice was proposed. In the discussion of manipulation of constraints according to Bernstein (1967), it is claimed that because there is no ideal pattern for movement, therefore exploratory practice should be considered [19]. Because the nonlinear method with the usage of constraint manipulation will help the learner try different types of solutions and discover the skill implementation strategy (high variability), so the effect of nonlinear practice on all variables (in this study, kinetic variables) is better than linear method. This issue can also be investigated by discussing degrees of freedom. In the freedom degrees discussion, it is argued that exploratory practice leads to the discovery of the different ways for each movement, or in other words, in exploratory exercises, one has more freedom of action to perform the movement [23], and since in the non-linear method practice is exploratory, it is also a lot of solution for skill action and learner available movement and because injury prevention requires a variety of solutions to select the most useful or best one. Therefore, in the nonlinear method, ACL injuries based on effective variables (kinetic variables) is less than the linear method.

The strength of this study goes back to the novelty of this study. Since nonlinear methods in the field of motor learning is a new training method that has been considered by researchers in this field in recent years, using it in the field of ACL injury prevention will be very helpful. However due to cultural problems, we could not use both sexes in selecting participants. Because it was not possible to combine both sexes and train them at the same time, and if they practiced separately, there would be problems in the type of practice and the coach's attitude. Therefore, we decided to use only men in this study, and future studies should consider this as limitation of this research.

CONCLUSION

In general, the results of this study emphasize the role of constraint manipulation in practice and learning and highlight the fact that nonlinear methods focus on exploration and search for solutions to prevent ACL injuries by affecting kinetic variables. These results extend the results of the Mohammadi Orangi et al. (2021) study and consider the nonlinear method as an effective strategy in clinical settings.

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مقایسه تأثیر آموزش خطی و غیرخطی بر عوامل خطرزای آسیب ACL: تأکید بر متغیرهای جنبشی در فرود بسکتبال

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چکیده:
در این پژوهش تأثیر روش‌های تمرین خطی و غیرخطی بر متغیرهای جنبشی در فرود بسکتبال بررسی شد و تغییرات نیرو و گشتاور از پیش‌آزمون به پس‌آزمون مورد ارزیابی قرار گرفت. پژوهش حاضر یک آزمایش نیمه تجربی و روش تحقیق بالینی بود و شرکت کنندگان ۲۴ نفر از دانشجویان دانشگاه خوارزمی بودند که به روش در دسترس انتخاب شدند و به مدت ۱۶ جلسه در دو گروه خطی و غیرخطی به تمرین مهارت های بسکتبال پرداختند. در روش خطی از ارائه الگوها و بازخورد برای آموزش و در روش غیرخطی از دستکاری محدودیت ها استفاده شد. متغیرهای اندازه گیری شده در این مطالعه شامل VGRF ، گشتاور فلکشن/اکستنشن زانو، گشتاور والگوس زانو و گشتاور دورسی فلکشن مچ پا بود. نتایج تحلیل کوواریانس نشان داد که روش غیرخطی در مقایسه با روش خطی تأثیر بهتری بر تمامی متغیرهای جنبشی دارد ($p<۰/۰۵$). نتایج این مطالعه روش‌های غیرخطی را به‌عنوان یک استراتژی مؤثر در محیط‌های بالینی می‌داند و بر نقش دستکاری محدودیت‌ها در تمرین و یادگیری تأکید می‌کند و این نکته را برجسته می‌کند که روش‌های غیرخطی با تمرکز بر کاوش و جستجوی راه‌حل‌هایی برای جلوگیری از آسیب ACL با تأثیرگذاری بر متغیرهای جنبشی کارآمد هستند.

واژه های کلیدی: روش تمرین، خطی، غیرخطی، متغیرهای جنبشی