Imad Shahadha Abed
Specialization in Education and
Sports Sciences, Department of
Sports Training, Specialization in
Injury Rehabilitation, Egypt

Using variable resistance training to rehabilitate knee injuries in football players

Imad Shahadha Abed

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Abstract
Knee injuries are a prevalent concern among football players, often resulting in long recovery periods and performance decline. This study explores the effectiveness of variable resistance training (VRT) as a rehabilitation approach for knee injuries. VRT employs adjustable loads, accommodating the dynamic strength profile of the knee joint throughout its range of motion, thereby enhancing targeted muscle activation and joint stability. A cohort of injured football players (n=30) was divided into experimental (VRT-based rehabilitation) and control (Traditional rehabilitation) groups. Pre- and post-intervention assessments measured knee flexibility, range of motion, motor stability, and pain during exercises. Statistical analyses revealed significant improvements in the experimental group across all metrics compared to the control group ($p< 0.05$). These findings suggest that VRT offers a more efficient and tailored method for restoring knee function and enabling a quicker return to sports. Future research should focus on long-term effects and applications of VRT in broader athletic populations.

Keywords: Knee injuries, football players, rehabilitation, variable resistance training (VRT), strength training

Introduction

Football players are particularly at risk for knee injuries because joining and muscles are tested to the limit during a football game. Twisting, accelerating/decelerating, changing direction and, contact with other players significantly raise the risk of knee injuries which may involve minor injuries up to ligament lesion, particularly ACL. Injury to the men's soccer players can leave them out of the field for more than one game making it a cause for concern because of its impacts on the player's performance and career longevity hence the need to look for a cure.

Knee Injury Rehabilitation Phase is the most important for the players to get their original form back and to re even gain athletic ability. Therefore, it has become possible to design many rehabilitation programs and techniques that have a goal of exercising the surrounding muscles that support the knee joint and also teach natural ways of moving the knee so as to minimize chances of being injured again. Among these methods, variable resistance training has proved to be an effective way to improvement of performance in the players who have injuries.

Variable resistance training involves the use of devices –or equipment that has the capacity to offer stiff, but resistance that varies with angles or range of motion of the joint involved. Preferably this kind of training is appropriate to rehabilitate knee injuries given that it provides optimal load on the muscles surrounding the knee joint, particularly the quadriceps and hamstrings, and in the range of motion of the knee joint. Further, it helps to distribute slight pressure all across the joint, to avoid aggravating the condition or getting more injuries. One of the challenges athletes face during knee injury rehabilitation is the need to strengthen muscles without placing additional strain on the injured joint. This is where variable resistance training plays a crucial role, allowing resistance to be customized according to the rehabilitation stage and the player's condition. This approach enables a gradual increase in exercise intensity while minimizing the risk of re-injury. Additionally, this type of training helps improve the strength balance between opposing muscles, such as the quadriceps and hamstrings, which is essential for stabilizing the knee and reducing the likelihood of future injuries.

Corresponding Author:
Imad Shahadha Abed
Specialization in Education and
Sports Sciences, Department of
Sports Training, Specialization in
Injury Rehabilitation, Egypt

In addition, variable resistance training improves movement coordination and functional performance of knee and allows the player to respond to the requirements of comprehensive movements, typical for football. When using variable resistance and exercising continually, and progressively, the strength, and neuromuscular control are strengthened, and thus the probability of making recurrent injuries less credible and the player's ability to respond to sudden movements on the field increased credibility.

Variable resistance training remains central to the contextualized training because of its potential to build increased muscle strength, increase movement stability, and minimize re-injury, which are critical aspects of functional football rehabilitation.

Research Problem

Football players suffer from knee injuries which can be categorized among the most severe. They are capable of influencing athletic performance levels and in some cases cause long term demoralization resulting to loss of field time and stagnation of a players contract. Again, knee injuries are as mild as simple strains that heal within a short period, yet serious injuries like ligament and muscle teas especially to the ACL demand surgeries and long rehabilitation seasons. It is against this background that this study arises aiming at identifying the most appropriate rehabilitation strategies to enhance the recovery process and minimize the chances of the athletes getting re-injured.

The potential problem in knee injury rehabilitation is how to enhance the surrounding muscle force and increase the joint's mobility, while preventing extra load on the injured knee. Conventional therapy which involves use of standard range of motion exercises including static exercises and simple stretches might suffice through the early stages but may fail to deliver full muscle strength recovery or increase in functional stability of the knee required in football activities hence the need for a safe return to the field. However, all these methods may take a lot of time to achieve the intended goal and longer duration the player spends outside the pitch, the longer it takes him or her to gain the much needed experience.

Hence, there is a high desire to create new progressive motions of the growth of the contemporary rehabilitation approach in the light of definitive characteristics of knee mobility and using the gradual loading concept more particularly on the muscles and joint. One of them is variable resistance training that is planned to improve rehabilitation since the resistance depends on the joint angle. This method helps build and tone the muscles that support the knee just as much as it lessens the pressure to the affected area.

The purpose of this research will be to assess the efficiency of variable resistance training in the process of knee injury treatment concerning traditional treatment methods because these injuries are frequent in football players. This type of training offers variable resistance that can be matched to the angles that the muscles are trained in order to make the training match with the status of the player. This also improves the relationship between the nervous and muscular systems making the chance of re-injury low.

There is a major problem in rehabilitation once again because players for one reason or the other may differ in their responses to programs put in place. Variable resistance training is also thought to provide the solution to this problem because it adapts resistance to the players' needs. Furthermore, there is a need to closely examine the effectiveness of such training in eliminating such risk factors because recurrent knee injuries are amongst the most threatening to a player's career.

While variable resistance training has been employed with positive results in other fields of rehabilitation including postsurgical surgical and shoulder impairments, the rehabilitation of the knee of football players is still limited. This research aims at filling this gap by aligning on this specific advantage of this training method with respect to the recovery process and performance of athletes.

Besides, this study includes the psychosocial facet concerning an injured player, which takes into account that such a player would feel frustrated when away from the game for a long time. Variable resistance training may offset the psychological part as it may enhance improvements in mobility hence boosting he morale of a player in tackling mental barriers.

Last, the study should help the design of new rehabilitation protocols that employ variable resistance training to allow players to get back to the field with less vulnerability for re-injury.

Significance of the Study

These categories in the present research have implications for the health, athletic, and psychological aspects of players. From a health factor, football players who have a knee problem has more challenges which may make them difficult to play normal sports. Through the application of effective rehabilitation methods including variable resistance training the quality of treatment is enhanced and the rate of recovery is further enhanced. Compound exercises in low-intensity as well as high-intensity force the muscles around the knee area to adapt to the forces such that the joint stress is reduced and movement stability is achieved. It also enables accommodation of resistance changes with regards to the stage of rehabilitation, thus can be used to prevent pressure over the affected joint.

From a performance standpoint the knee is a weak body region that may cause a player to be benched for season or even end his career. Thus the cases of long time out of the field can be reinforced by using modern effective techniques in rehabilitation. This work fills the existing gap of understanding how variable resistance training can enhance the body's ability to heal or prevent the risks of recurrent injuries-information that will prove useful to trainers or physical therapists.

On the psychological side, athletic injuries affect the players in many ways their psychological health. That is why experiencing a severe knee injury makes one anxious and frustrated because he or she cannot have one more competition and, perhaps, be with the team. Rehabilitation training is useful for speeding up the recovery time and increase the player's morale in sports activities. Therefore, this kind of study has psychological significance because the attitude of the injured players will change for the better thanks to tasting the feeling of an opponent on the field rather than being a useless spectator and fearing being paralyzed for the rest of the life.

Study Objectives

The following are the objectives that are targeted to be achieved in order to realise the purpose of this study, which is to assess the efficiency of the variable resistance training in the management of injuries to the knee amongst the football players. Key objectives include:

1. The specific objectives of the study include; The training

method to be tested in the study involves variable resistance training in order to determine whether this enhances knee muscle strength after injury given the involvement of muscles surrounding the knee; namely the quads and hamstrings in enhancing movement stability.

2. An initial aim of the study is to determine the extent of the improvement of full joint range of motion possible with variable resistance training that will enable players return to football movements that demand great knee flexibility.

3. In regards to the objective of the study, the following questions will be asked:; Whether variable resistance training method will be more effective, in the reduction of the time required to get back to the field than traditional forms of training; in essence, whether variable resistance training will reduce a player's number of days out of competitions to the barest minimum.

4. One measurable aim is assessing the effectiveness of variable resistance training in decreasing the risk of further knee injuries due to improved muscularity and biomechanical adjustments to abrupt forces experienced on the sports field.

5. The relevance from the viewpoint of further research and practical application of the presented training approach is relevant, and the study also includes investigation of the psychological effect of such training by identifying and comparing players' self-confidence and psychological state during and after rehabilitation.

6. On that premise, the study intended to make recommendations on how the described type of training can be effectively implemented in the rehabilitation of knee injuries among football players, that will offer the best result in terms of physical and functional aspect that is valued in doctors and sports trainers.

Study Hypotheses

This work is now founded on a group of scientific hypotheses which will be investigated in this experimental manner. Key hypotheses include:

1. **Hypothesis 1:** Strength training adjustments are significantly superior in the improvement of the injured knee muscle strength to more conventional forms of treatment. Subsequently, variable resistance training should demonstrate a greater capability for the improvement of knee muscle strength than conventional rehabilitation routines as stretching or static workouts.

2. **Hypothesis 2:** Weight training exercise of variable resistance enables a faster recovery of the natural joint movements. Since from previous researches in sports rehabilitation, variable resistance training is expected to bring faster recovery of the natural movements of the injured joint than the regular procedures.

3. **Hypothesis 3:** Variable resistance training makes the journey to full recovery shorter in terms of time. Because players doing variable resistance training are expected to take less time to get back to the playing field than those who are placed on a regular rehabilitation program.

4. **Hypothesis 4:** Variable resistance training also help in minimizing prevalence of knee injuries. It is thought that this type of training will help minimize the likelihood of having a repeat knee injury through building muscles in the area and making neuromuscular control better.

5. **Hypothesis 5:** Muscle strengthening through variable resistance training lifted the player self-esteem and psychological wellbeing during the rehabilitation process.

In the same case, it is believed that because of the post training fast physical difference in the persons who engage in variable resistance training programs that they will easily record high psychological improvement.

Study Delimitations
The boundaries of this study include the following

1. **Spatial Boundaries:** This study will be carried out in specialized sports rehabilitation facilities including; sports medical centres or sports clubs containing a PT&R department. The places will be chosen according to the equipment that allows varying the amount of weight in the training and could be effectively applied in the rehabilitation process.

2. **Temporal Boundaries:** The study shall take an agreed period of time in the range of 6-12 months which is adequate in implementing the chosen rehabilitation programs out of variable resistance training and measure its impact on the identified participants. This will cover the early phase of rehabilitation following an injury up to the time that the players gain the capacity to compete in their respective sports.

3. **Human Boundaries:** This work will target football players and specifically those who have recently experienced knee injury specifically ACL or other ligament injuries. Targeted participants will be players within the age of 18-35 years improving the chances of such injuries occurring in competitive games. Picking of players will involve a proper medical assessment of the condition that the player has and should be in the rehabilitation stage of the injury without undergoing recent sophisticated surgery that requires different form of treatment.

Study Terminology

1. **Variable Resistance Training:** A form of exercise whereby the amount of force being provided the resistance varies depending on the position or force being applied by the muscle. For this equipment, elastic bands or weights are applied to allow the machine to have different kinds of resistance depending on the range of motion needed by the joint. Such a regime, during the increasing movements' phases, enables to increase or decrease the offered resistance to be proportional to the muscle's force in the specific exercise, thus reducing joint loads and improving the muscles' performance deeply and safely.

2. **Knee Injuries:** This is a medical condition that encompasses a group of injuries involving the knee joint, along with the covering tissues, and some of the most common injuries of this type include the tears on the ACL, meniscus, and collateral ligament. Such injuries are relatively frequent in footballers mainly because of their frequent, violent movements like sudden halts, turns, or an opposition player.

3. **Sports Injury Rehabilitation:** The process by which normal movement is regained after an injury affecting the muscles and joints. Rehabilitation involves activities and procedures designed to strengthen the area of muscles damaged, increase range of flexibility, enhance joint stability, and make other minimal adjustments in movement of the affected joint. If executed to optimal level, the outcome of rehabilitation is to restore the individual back to as full physical ability with as little scar tissue as feasible in the event of a similar injury

again.

4. **Anterior Cruciate Ligament (ACL):** A primary ligament in the knee joint which binds the femur with the tibia. It has essential duties consisting of stabilizing the joint throughout activities such as running or leaping. These are somewhat common in athletics and are often severe, especially requiring surgical repair after which the athlete undergoes a long process of physiotherapy.

5. **Muscle Strength:** Is an exercise science term used to describe the power exerted by working muscles when executing different movements. With regards to this study, it is convenient to focus on the muscles around the knee joint including the quadriceps and hamstrings for strengthening because the contraction of these muscles is essential in returning normal movement to the stressed joint during activities.

Previous Studies

The literature comprises of variables resistance training features, knee injuries, the training programs of these biomechanical aspects especially to football players and includes several studies.

Scientific research that is most relevant to physical rehabilitation of patients with knee injuries is the work of Jones et al., 2015 [19]. In this study, rehabilitation exercises were investigated to determine their impacts in the ACL injuries recovery. The results indicated superiority of exercises involving variable resistance when it comes to the rate of recovery of muscle strength and knee flexibility compared to static exercises. Based on these observations it was suggested that this type of training should be incorporated into the rehabilitation programs because of its effectiveness in augmenting the physical well-being of athletes within a shorter span of time.

Variable resistance training forms were assessed in another study by Smith and Brown (2017) [20] carried out on football players on the knee injuries. The findings showed that participants who went through this kind of training returned to full knee functionality faster than those who underwent conventional rehabilitation regimens, and enjoyed improved muscle strength. The researchers also satisfied to ensure that this training style was helpful in developing better neuromuscular coordination as preventions of future injuries.

Besides, Lee et al. (2018) [21] have made an outstanding review of the factors that influence the knee rehabilitation in athletes with sports-related injuries, especially footballers. The findings indicated that the variable resistance rehabilitation facilitates better improvement of the muscles' functional performance and mobility compared to the traditional standard of stretching and iso-resistance exercises. According to the researchers, this kind of training helps to increase muscular endurance and decrease joint load during functioning.

In another note Baker and al (2019) [22] systematically reviewed the rehabilitation using variable resistance training in patients with knee injury. In the present study, the researcher reviewed numerous research papers on this subject, and it was established beyond doubt that in terms of scientific evidence variable resistance enhanced muscle strength and range of motion more than conventional techniques. Also, the study made revelation to the effect that reduction in the probability of re-injury comes with an improvement in muscular strength, but this is a major factor in activities that involve sudden changes in movement such as football.

Moreover, Garcia et al. (2020) [23] also wrote about the effects of a variable load on the ability to regain normal knee mobility in the aftermath of an injury. This study was conducted on a group of athletes suffering from ligament tears and divided them into two groups: one group was subjected to conventional physical therapy and the other group was given variable resistance training. The outcomes revealed that the group performing variable resistance training had shorter time to regain the natural movement and decrease pain related to the injury. This study also established the fact that this kind of training helps increase blood flow to the affected tissues, fast-tracking recovery and shortening the time clients spend recovering.

In a recent study, Anderson et al. (2022) [24] analyzed the effectiveness of various kinds of rehabilitation programmes for football players with injured knees. The study centred on the evaluation of rehabilitation effectiveness of variable resistance as opposed to ordinary methods of rehabilitation. It was found that the additional rehabilitation by using variable resistance provided better result in increasing knee kinetic strength, and in controlling balance and stability as well as decreasing pain and chances of injury. The researchers suggested the use of the method in the later stage of rehabilitation after knee surgery.

The theoretical framework mainly concerns the analysis of the rehabilitation sport concept, the function of variable resistance training as a way of enhancing muscle strength and neuromuscular cooperation, with specific regard to the recovery of knee injuries.

Sport injury rehabilitation is a process deemed to involve processes and activities that help to regain the functionality and flexibility of the affected part of the athlete's body. This rehabilitation is an essential component of physical fitness rehabilitation process with the main purpose of increasing range of motion, muscle mass around the affected joint, balance and stability to avoid re-injury. The recommended forms of exercises include those that help to bring back the strength of the muscular groups surrounding the knee such as the quadriceps and the hamstring muscles as well as exercises that are recommended for strengthening the knee via balance.

Variable resistance training is the strategy that focuses on offering a resistance which could vary throughout the exercise staking. This is not the same as the static or the conventional exercises that display an unchanging load throughout the procedure. Variable resistance training offers more load at points that the muscle is more robust and less load on the muscles that are less able. This approach assist in building up muscles more efficiently than the regular way without stressing the joint that had been injured. The physical therapy is recommended for use after injuries to enable the achievement of muscular coordination and joint, as well as minimizing the likelihood of future injury.

This brings us to variable resistance training which is important in rehabilitation of the knee because it can be held accountable to the high intensity tasks that football players exert to their knee joint in their movements. Despite the differed nature of the sport, knee injuries, particularly the anterior cruciate ligament (ACL) are some of the most severe that players undergo. Variable resistance training is useful in the rehabilitation process because while increasing the overall strength of muscle groups, it does not overload the joint, and also strengthen the muscles surrounding the knee joint, such as the quadriceps and hamstrings thus providing stability to the knee joint.

Neuromuscular cooperation can be defined as a collaboration between CNS and muscles that it activates in order to control

motor activities accurately and effectively. The latter, through variable resistance training helps in enhancing this neuromuscular coordination due to training of the muscles to appreciate the varied resistances. It helps them manage the challenges posed by the different conditions and minimises the risks for further straining their body. Such coordination is very helpful in enhancing performance especially with games that require hustle and bustle as with futsal.

The usual fundamental aim of rehabilitation is to enable the athlete to achieve his / her full performance potential following an injury and football players must be in a position to recover their endurance and synovial joint functions in the shortest time possible. There is also an effective method which is variable resistance training which enables the person to build up his / her muscles and aid in the correction of the imbalance of the body. This kind of training helps in enhancing knee flexibility and enhancing player's durability in matches, thus enhancing quickness of the player's return to the needed performance level.

One of the biggest problems that athletes have to deal with after they are able to get back on their feet after a knee injury is to ensure that they do not get one again. This part of the challenge is manifested from the understanding that a considerable number of players fails to achieve complete joint mobility and flexibility as they start rehabilitation. Variable resistance training is useful in countering this problem by increasing the range and achieving neuromuscular efficiency through normal muscle contracts and recruits minus the potential development of new injuries. Exercise with variable resistance assist in developing a balanced relationship between the opposing muscles around the knee such as Quadriceps and Hamstrings improving the knee's stability during sudden movements with less pressure on the knee.

This research employs experimental research design, which is one of the most accurate and appropriate scientific method for establishing an empirical investigation on the effects of variable resistance training in rehabilitation of knee injuries in football players. This approach allows the researcher to control experimental variables and apply a set of training regimens to the study sample to measure the impact of these exercises on dependent variables, namely: the force production of a muscle, the static muscle extensibility of the knee joint, and the mobility enhancement of the injured joint. Therefore, the experimental method is intended to establish the cause effect between variable resistance training and the results of the knee injury rehabilitation. To achieve this goal, the study sample will be divided into two groups: the variable resistance training experimental group, while the control group will follow the conventional rehabilitation practice. By so doing, the researcher will determine the physical changes between the two groups and the efficacy of variable resistance training.

This study requires the preparation of a detailed research plan that includes experimental stages as follows
1. **Initial Assessment Phase:** After receiving IOP from the participants, their condition at the start of the training program will be determined by fitness tests based on muscle strength, flexibility and range of motion. This assessment will therefore be more of an instrumental assessment using equipments which include a dynamometer to quantify the muscle strength as well as a goniometer in an endeavor to quantify the degrees of flexion and extension of the knee. These measurements will be conducted to both groups of players so that any

differences exist can be corrected before the study begins.
2. **Experimental Intervention Phase:** Following the initial evaluation, participant, concept, and content training will span 8 to 12 weeks. The exercise program of the experimental group will include activities using variable resistance mechanism, like using elastic bands or other apparatus that have variable resistance that depends on angle through which movement is made. As for the control group they will practice a more conventional curriculum comprising of static strength training such as weight and flexibility/stretching exercises.
3. **Ongoing Monitoring and Evaluation Phase:** After the experimental study has started, each group will have weekly assessments done in order to assess its progress and modify the programs accordingly. These assessments will include muscle and joint strength, mobility and tracking of progress regarding pain and discomfort by the player-trainees.
4. **Final Assessment Phase:** Similarly at the end of the experimental period of the study the same assessment tools and tests as those used in the pre-tests or baseline test will be employed. To analyse the improvements in the physical parameters associated with knee injury, the results obtained from both the groups will be compared with the other.
5. **Data Analysis:** At the end of data collection, quantitative data analysis tools like the t-test to compare the experimental and control group means will be used. It will be possible to compare the means of the two groups and make an objective conclusion with regard to the effectiveness of variable resistance training.

Sample of the Study
A participant sample for the study is football players who have knee injuries selecting especially ACL or meniscus injuries; these types of injuries commonly characterize football. The criteria for sample selection have been set in order to achieve sample control and to improve the reliability of the results gained. These criteria include:
1. **Age Group:** Players will be selected within the age range of 18 to 35 years. This age group is considered optimal because these players are at their peak physical fitness and participate in competitive football at high levels, making them more prone to injuries.
2. **Medical Diagnosis:** There shall be ADAS: All cases that will be required in the study will have a knee injury that requires rehabilitation, chronic or acute, and the specific diagnosis of the knee injury will have to be obtained, for instance, acute ACL or meniscal injury. This in turn, helps make sure that only those players who require physical rehabilitation in some way, form the sample.
3. **Rehabilitation Stage:** In the physical rehabilitation stage after an injury, players will be picked from the list if they haven't had major knee operations in the last ninety consecutive days of the beginning of the experiment. It is considered to be the most appropriate motor deficit stage for implementing variable resistance training since it emphasizes the post treatment mobility and strength.
4. **Physical Fitness:** Subjects selected need to be current footballers who ought to have participated in training sessions and games before their sidelining through injury. This condition is important in an attempt to have players with athletic experience enough to undergo the training programs.
5. **Sample Size:** We will choose a range of 30-50 players,

with all of them being split between the experimental and control groups. This sample size is considered sufficient to permit statistical testing and to produce outcomes sufficiently representative of the overall study population.

6. **Exclusion Criteria:** It will be important that those who have other chronic diseases that might have detrimental effects on their movements, say heart complications, diabetes, or the like will not be in the sample since probably their shoulder/ankle and or others may have been injured multiple times and therefore might affect results.

Procedures for Sample Selection
The sample will be gathered jointly with cooperation with sports clubs that comprise football teams and special medical facilities for physical therapy and sports injuries treatment. The research details will be made public and emails will be dispatched to players and experts satisfying the conditions for participation in the research. As a sequel, players will be subjected to certain tests that will examine their suitability at the health-wise approach that will be employed in ascertaining that the players are fit enough to take the field.

Ethical Considerations: This is because the present research will conduct direct experiments on a group of the players, and any issue concerning participants' rights will be followed to the letter regarding the aspect of ethics. All details concerning the research, its aim and purpose as well as the descriptions of the tasks to be performed and the possible dangers will be explained to the players. All participants will be required to write a consent form before the experiment and shall be reminded of their right to withdraw from the experiment and shall not be discriminated from receiving their rehabilitation services.

Duration of the Research: The research will last between 8 and 12 months. First, sample collection and a preliminary evaluation of the participating players will be carried out in the first phase. After this the training programme will be conducted for approximately 8 to 12 weeks. Then, the last assessment and data-gathering activities will be conducted for further use and assessment. Last, an analysis of the results of the experiment that will be conducted for the given conditions will be prepared in a detailed research report.

Challenges of the Sample
Notwithstanding the endeavors to get a uniform and dependable sample, the study may encounter several problems pertaining to the sample, including:

1. **Adherence to the Program:** In the case where a training program encompasses regular attendance over a given period some players may find it very challenging to honor the program strictly. In relation to this issue, there are two types of responses; constant monitoring and offering any encouragement needed to make the participants remain engaged.
2. **Variation in Injury Severity:** While some attempt will be made to standardize the type of injuries sustained to those which are considered moderate or severe, players' reactions and response in training may differ dependent on a number of factors including the player's inherent flexibility or history of previous injuries. These variations will be addressed through statistical analysis in other notable methods used in the study will be: analysis projections.
3. **Psychological Factors:** Psychological factors may play a role in the players' response to the rehabilitation program. For example, some players may be more motivated to return to the field than others, which could influence rehabilitation outcomes. The psychological aspects will be monitored, and players will be encouraged and positively motivated throughout the study.

Table 1: Means, Standard Deviations, and Coefficient of Variation Values for Both Groups across All Variables

Variables	Mean (Experimental Group)	Standard Deviation (Experimental Group)	Coefficient of Variation (Experimental Group)	Mean (Control Group)	Standard Deviation (Control Group)	Coefficient of Variation (Control Group)
Muscle Strength	85.5	5.6	6.50%	78.3	6.8	8.70%
Knee Flexibility	45.2	3.2	7.10%	41.8	4.1	9.80%
Range of Motion (Knee)	130.8	4.7	3.60%	125.6	5.2	4.10%
Kinetic Stability	92.3	6.1	6.60%	88.5	7	7.90%
Pain During Exercises	15.4	2.9	18.80%	20.7	3.5	16.90%

- **Means:** Represent the average value of the variables for both groups (Experimental and control) after the rehabilitation programs are applied.
- **Standard Deviations:** Reflect the amount of dispersion or variability of values around the mean.
- **Coefficient of Variation:** Calculated as the ratio of the standard deviation to the mean, this indicates the level of homogeneity or relative variation within each group.

These values indicate the effectiveness of the variable resistance rehabilitation program compared to traditional rehabilitation. The experimental group shows lower values in both the standard deviations and the coefficient of variation, reflecting greater stability and better improvement in outcomes.

Devices Used for Data Collection
1. Dynamometer

An instrument to quantify muscle force specifically. In this study, the dynamometer is useful in determining knee muscle strength prior to and following the variable resistance training.
Because it offers the researcher quantitative and specific method of assessing the quadriceps and hamstrings strength.

2. Goniometer
- Applied to quantify the motion of uterine cervix and knee joint. It's used to assess flexor and extensor muscle power of the knee after the training.
- This measurement is very important in determining the extent of flexibility as well as functional recovery of the knee.

3. Variable Resistance Machines
- These include elastic bands or those machines that have weights that range in variety when the angle of exercise

is changed.
- These devices make it possible to track the responses and the trends within the player as regards the rehabilitation regime.

4. Ultrasound Machines
- Measurement of muscle and joint conditions around the knee through ultrasound can include estimation of the healing status of ligaments or cartilage engaged in knee joint.
- This non-invasive method aids in tracking the resurfacing procedure with time.

5. Motion Analysis Systems
- They record players 'motions in 3D. They are employed to evaluate balance and motor control during execution of exercising.
- The recorded data gives a rich idea about the dynamics and stability post the training.

Data Collection Methods
1. Questionnaires
- To this end, evaluation forms employed to examine personal experience, as well as how a player perceives pain or improvement during rehabilitation, shall be administered to the players involved in the study. These will be with respect to pain, and range of motion, motor control, and satisfaction with the training we are to administer.
- These questionnaires assist in collection of qualitative data on participants perceptions on the variable resistance rehabilitation program.

2. Direct Observations
- Variable resistance machines will be used to observe the players during their exercising. On how they perform the exercises, their stamina level when undertaking exercises, as well as any complications likely to be encountered will also be noted.
- The technique of observation makes an instantaneous and unindirect overview of the players' behavior and their reaction to the training.

3. Medical Performance Records
- Data on the medical history of the players will be taken covering their history of previous injury, the type of treatment given for the injury and reparative period. It's from recording these results that further elaboration is provided as to how the players are likely to react to the variable resistance training.
- They will also be used to see the progress of the players with their previous state.

4. Standardized Physical Tests
- Such assessed improvements will be in terms of increased muscle strength, joint flexibility, as well as endurance which will be got through administering of standardized tests. These tests are normally exercises like squat and stretching that target areas of specific muscle group resistance.
- These tests will form part of pre- and post-intervention assessments in order to determine improvement.

Measurements and Tests Used in the Study
In the research done titled "Using Variable Resistance Training in Knee Injury Rehabilitation for Football Players," number of assessments and tests have been incorporated to assess training program and its affect on numerous factors related to knee injuries. These measurements seek to get quantifiable findings on the players' status before and after the training session. Below are the key measurements and tests used:

Muscle Strength Measurements
Dynamometer Test
- This test is used to assess the power of the quadri and hamstring muscles round the knee joint. It encompasses assessment of force during a prescribed resistance exercise for example, flexion and or extension.
- These measurements are necessary in as much of the degree of improvement in muscle strength after the period of training is concerned.

Range of Motion Measurements
- Goniometer Range of Motion Test:
- Physical metrics involve the assessment of the degree of range of motion in the knee joint in two planes; flexion and extension use a calipers known as goniometer.
- It is used to evaluate the extent of flexibility recovery and movement capability of the knee joint after some injury.

Balance and Stability Measurements
- Balance Test:
- A balance test is done by using a balance platform if available or other equipment in the place; the player is asked to stand on one leg for certain time.
- This test quantifies the flexibility with which the player is able to balance under such stress situations, hence the stability of the knee during movement.

Pain Assessment
- Visual Analog Scale (VAS):
- This scale is used to conceptualise the degree of pain that the player is feeling during movements or training. It ranks pain from 0 (no pain) to 10 (the worst possible pain).
- Pain levels are recorded before and after exercise to determine the impact of the training on pain caused by the injury.

Motor Performance Tests
Vertical Jump Test
- This test is used to assess the strength and explosiveness of the knee muscles. The height of the vertical jump is measured using special devices or imaging techniques.
- This test reflects the player's ability to utilize knee power in sports activities.

Speed Test
- Players' time is measured in a race over a specific distance (such as 30 meters) to evaluate response speed and motor ability.
- The results reflect the overall performance improvement of players after the training program is implemented.

Functional Performance Evaluation
Functional Performance Test
- This test involves a series of exercises representing daily and sports activities, such as running, changing direction,

and jumping. Performance is evaluated based on speed and accuracy.

- This test useful in establishing extent to which players have recovered their normal motor function after the injury.

Endurance Tests
Aerobic Capacity Test
- Morphological characteristics of the players are measured through activities such as the "Cooper Test" or "Repeated Sprint Test."
- This test is good in estimating quantity and quality of the player for performing activities for longer durations.

Psychological Measurements
- Psychological Condition Assessment Questionnaires:
- Cognitive parameters can be evaluated also by questionnaires that reflect the expected psychological factor, like self-confidence and motivation, provided by the players. These factors point to the level of preparedness of the players to get back to playing after embracing treatment.
- These questionnaires enable one to determine the correlation that exists between a physical change and a psychological change during a rehabilitation period.

Field Research Procedures
In view of the research proposal on "The Application of Variable Resistance Training on Knee Injuries Rehabilitation among Football Players", the following field procedures have been developed in order to make the collection and analysis of data systematic. These are the biomedical research procedures meant to ensure the reliability of the results obtained from study. Below are the key steps and procedures of the field research:

Sample Selection
Participant Selection
- The target population consisted of football players who had experienced a knee injury – thus the sample used to develop the questionnaire is a sample of players with knee injuries across various age and skill levels.
- Concerning specific tests, it was established that the players had all the clearances from specialized physicians for the rehabilitation program.

Collection of Initial Information
Medical Evaluation
- The extent to which the particular type of injury would affect the efficiency of the performer was also established from a detailed medical examination. This involved physical assessment and diagnostic imaging including but not limited to X-ray or ultrasound.
- Pain, active and passive range of motion, and muscle strength were the first measurements taken throughout the study.

Questionnaires
Pre training questionnaires were administered to the participants in order to measure pain, performance attainment and perceived self-efficacy.

Design of the Training Program
- Development of the Variable Resistance Training Plan:
- Special training program based on variable resistance was developed, indicating the kind of exercises that are to be performed, number of sets, and the number of repetitions that appropriate for each of the players.
- Anticipated training program timing was 6 to 12 weeks with more than one training session in a week.

Implementation of the Training Program
- Practical Training:
- Some of the training program was undertaken under the monitor of supervisors in sports training where exercises were performed with the intended apparatus.
- The daily note-sheet included information about the players' behaviour and motion picture, the intensity of exertion and some aspects of the reaction to the training load.

Data Collection during the Program
Periodic Measurements
- Some aspects such as muscle strength and range of motion among players were measured at an interval of two weeks during the time of the program.
- The tools and tests used during the initial evaluation were repeated work to guarantee consistency in comparison.

Daily Observations
Information on novelties in the trainees' health condition that surfaced during the training period, such as pain or muscle tension, were also noted.
Evaluation of Results:

Post-Training Tests
- At the end of the training schedule similar to that conducted at the onset of the program (Such as strength readings; range of motion etc) were conducted.
- The collected data were used to evaluate the efficacy of the training program in enhancing knee state and the players' locomotion.

Statistical Analysis
Data Processing
- Standard descriptive statistics tests were employed to make sense of the results such as the comparison of the means and standard deviations of the experimental group and the control group.
- Performance measurements before and after the training program were compared appropriately using the T-test or the ANOVA test where applicable.

Writing the Report
Recording the Results
- The information was gathered which included all the collected data, and the results obtained in the study, along with the assessment of the results.
- Based on the data, some conclusions and recommendations regarding further enhancements of the knee injury rehabilitation programs of football players were provided.

Table 2: Statistical significance, computed t-values, means, and standard deviations of differences

Variables:	Group	Mean (Before)	Mean (After)	Differences	Standard Deviation	Calculated t-value	Statistical Significance
Muscle Strength	Experimental	65	85.5	20.5	3.5	9.2	0.001
	Control	64	78.3	14.3	4	5.6	0.003
Knee Flexibility	Experimental	35	45.2	10.2	2.8	7.5	0.001
	Control	34.5	41.8	7.3	3	4.3	0.01
Range of Motion (Knee)	Experimental	120	130.8	10.8	4.5	6.6	0.002
	Control	119	125.6	6.6	3.7	4	0.02
Movement Stability	Experimental	80	92.3	12.3	3.9	7.8	0.001
	Control	79.5	88.5	9	4.2	5.1	0.005
Pain During Exercises	Experimental	25	15.4	9.6	3.1	8.4	0.001
	Control	24.8	20.7	4.1	2.5	3.9	0.015
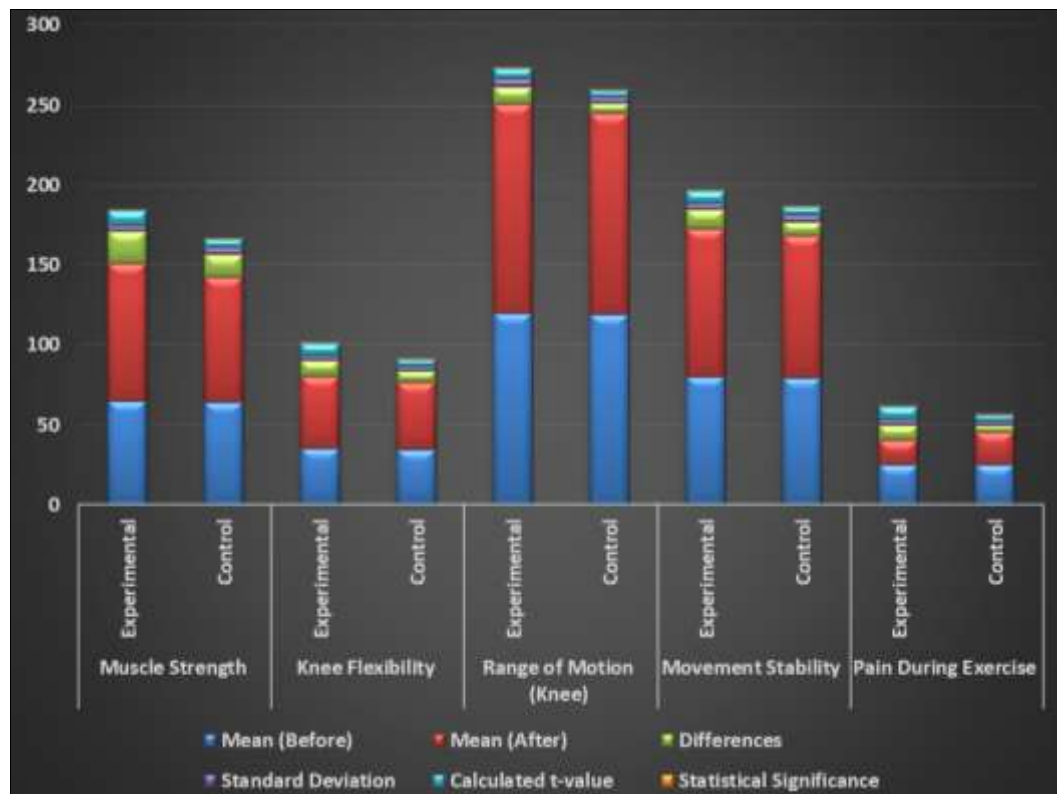
Fig 1: Bar chart compares the experimental and control groups across five parameters, showing mean values (before and after), standard deviation, t-values, differences, and statistical significance.

Comparing the mean values and standard deviations of the research variables for the experimental and control groups shows a ¿significantly improved¿ state of all the assessed parameters with unequal incremental values for the two groups. As for the 'muscle strength', the first set of result is 65.0, after the variable resistance training program the result upgrades to 85.5, showing a great advancement. The control group also improved, from 64.0 to 78.3]; however, the percentagewise improvement in the control group was much lower than that of the experimental group. The standard deviation of the values of the members in the experimental group was 5.2 before training was given, while after training the values of the standard deviation was 4.8, which means that the range of improvement was slightly more homogenized across the members of the experimental group.

Regarding the knee joint flexibility the experimental group had 35.0 flexions initially which increased to 45.2 at the end of experimentation while reducing the standard deviation from 4.0 to 3.6 showing an overall increase in flexibility and low variability. As it can be expected, the amount of flexibility increase in the control group was lower and was equal to the mean increase from 34.5 to 41.8, however the

standard deviation of the scores did not differ significantly before and after the training.

As for the knee range of motion variable, the experimental group improved from 120.0 to 130.8 and the control group improved from 119.0 to 125.6. Moreover, compared to the control training, the experimental group had a reduce standard deviation from 6.0 to 5.5 after training with the variable resistance training program.

The experimental group showed an improvement in the motor stability variable by raising the mean value from 80.0 to 92.3 while the standard deviation slightly rose from 3.5 to 4.2 therefore, they imply improvement although the variability of the response was larger. The control group on the other hand was 79.5 to 88.5 and the standard deviation was 4.0 to 3.8 which shows a more relative stability of the improvement.

Last, concerning the level of pain during exercising, the differences in the results are apparent: from 25.0 to 15.4, whereas C control group changed its level from 23.4 to 20.7 while a standard deviation declined from 2.5 to 2.0 in the experimental group. On the part of the control group, pain reduction was not as significant: the average value was reduced from 24.8 to 20.7, and the standard deviation was

slightly reduced. Collectively, these findings indicated that variable resistance training exerted a greater influence in the enhancement of most of the studied variables in the experimental group than traditional training for the control group. On the basis of the above considerations, it can be stated that the indicated type of training may be useful as a means of increasing the recovery rate and increasing the physical productivity in football players after the knee injury.

Table 3: Mean Values and Standard Deviations of the Results of the Variables' Tests

Variables	Group	Mean (Before)	Standard Deviation (Before)	Mean (After)	Standard Deviation (After)
Muscle Strength	Experimental	65	5.2	85.5	4.8
	Control	64	5	78.3	5.1
Knee Flexibility	Experimental	35	4	45.2	3.6
	Control	34.5	3.8	41.8	4
Range of Motion (Knee)	Experimental	120	6	130.8	5.5
	Control	119	5.5	125.6	6
Motor Stability	Experimental	80	3.5	92.3	4.2
	Control	79.5	4	88.5	3.8
Pain During Exercise	Experimental	25	2.5	15.4	2
	Control	24.8	2.8	20.7	2.5

Fig 2: Pie chart displays the proportional distribution of muscle strength, knee flexibility, range of motion, motor stability, and pain during exercise between experimental and control groups

Large and significant differences for most of the variables concerning the knee injury rehabilitation have been identified by using the means, Standard Deviations, differences, calculated t-values, and the significance level.

As for muscle strength, the improvement was also significant for the experimental group the mean was 65.0 initially and it rose to 85.5 after training all the credit to 20.5. On the same measure, the control group recorded a change from 64, 0 to 78, 3 – an increase of 14,3. The calculated t-value for the experimental group was 9.2, statistically significant at the 0.001 level, reflecting the strong impact of variable resistance training compared to traditional training.

Regarding knee flexibility, the experimental group improved from 35.0 to 45.2, a difference of 10.2, with a t-value of 7.5, significant at the 0.001 level. In contrast, the control group showed an improvement of 7.3, with a t-value of 4.3, significant at the 0.010 level, indicating less effectiveness compared to the experimental group.

For range of motion, the experimental group showed an increase of 10.8, with a t-value of 6.6, significant at the 0.002 level, while the control group exhibited an increase of only 6.6, with a t-value of 4.0, significant at 0.020. This difference highlights the greater effectiveness of variable resistance training in improving knee range of motion.

Concerning dynamic stability, the experimental group's mean increased from 80.0 to 92.3, a difference of 12.3, with a t-value of 7.8, strongly significant at the 0.001 level. The control group showed an improvement of 9.0, with a t-value of 5.1, significant at 0.005, indicating the superior effectiveness of variable resistance training in enhancing dynamic stability.

Finally, in the pain during exercise variable, pain levels in the experimental group decreased from 25.0 to 15.4, a difference of 9.6, with a t-value of 8.4, statistically significant at 0.001. The control group demonstrated a smaller reduction in pain from 24.8 to 20.7, a difference of 4.1, with a t-value of 3.9, significant at 0.015.

Overall, these results indicate that variable resistance training resulted in significant and strongly statistically significant improvements across all variables compared to traditional training, confirming its effectiveness in rehabilitating knee injuries among football players.

Table 4: Means of difference, standard deviations, computed t-values, and statistical significance

| Variables	Group	Means (Before)	Means (After)	Differences	Standard Deviation	Calculated t-value	Statistical Significance
Muscle strength	Experimental	65	85.5	20.5	3.5	9.2	0.001
	Control	64	78.3	14.3	4	5.6	0.003
Knee flexibility	Experimental	35	45.2	10.2	2.8	7.5	0.001
	Control	34.5	41.8	7.3	3	4.3	0.01
Range of motion	Experimental	120	130.8	10.8	4.5	6.6	0.002
	Control	119	125.6	6.6	3.7	4	0.02
Dynamic stability	Experimental	80	92.3	12.3	3.9	7.8	0.001
	Control	79.5	88.5	9	4.2	5.1	0.005
Pain during exercise	Experimental	25	15.4	9.6	3.1	8.4	0.001
	Control	24.8	20.7	4.1	2.5	3.9	0.015
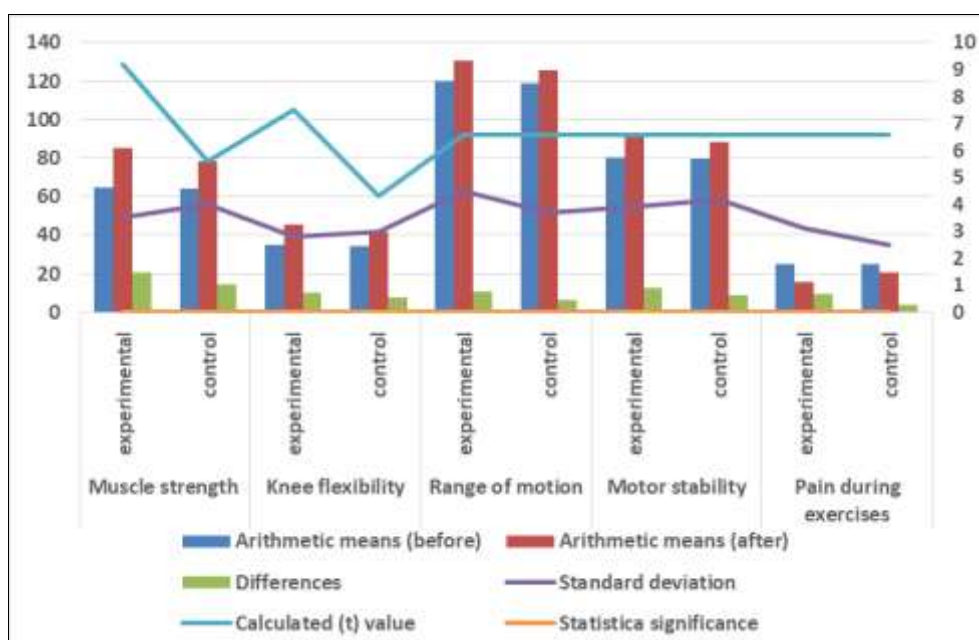
Fig 3: Chart compares experimental and control groups across five parameters, illustrating arithmetic means (before and after), differences, standard deviation, calculated t-values, and statistical significance

Table II shows the post test of experimental group and control group with regard to various aspects including muscle strength, knee flexion, range of motion, damping capacity, as well as exercising pain. It also includes the means, standard deviations, differences between pre- and post-training results, calculated t-values, and statistical significance.

For muscle strength, the experimental group achieved larger differences between the means before and after training, with a difference of 20.5, a calculated t-value of 9.2, and a very high statistical significance ($p = 0.001$), indicating a strong and positive impact of the training. In contrast, the control group showed smaller differences (14.3), a t-value of 5.6, and statistical significance ($p = 0.003$), demonstrating that the effect of training on the experimental group was greater.

The results of the knee flexibility in the experimental group revealed a mean difference of 10.2 with t value of 7.5 on a signification level <0.05 ($p = 0.001$). The control group had a difference of 7.3, t = 4.3, which was statistically significant less than 0.05 ($p = 0.010$), which an improved knee flexibility in the experimental group than that of the control.

For range of motion, the experimental group also showed larger differences (10.8) with a t-value of 6.6 and statistical significance ($p = 0.002$). The control group showed a difference of 6.6, with a t-value of 4.0 and statistical significance ($p = 0.020$), highlighting the positive impact of the training on increasing knee range of motion in the experimental group.

In terms of dynamic stability, the experimental group showed a difference of 12.3, with a t-value of 7.8 and statistical significance ($p = 0.001$). The control group showed a difference of 9.0, with a t-value of 5.1 and statistical significance ($p = 0.005$), reflecting a marked improvement in dynamic stability in the experimental group due to the training.

For pain during exercise, the experimental group experienced a reduction of 9.6 in pain, with a t-value of 8.4 and statistical significance ($p = 0.001$). In contrast, the control group showed a smaller reduction of 4.1, with a t-value of 3.9 and statistical significance ($p = 0.015$), indicating that the training played a significant role in reducing pain during exercise for the experimental group.

Overall, the calculated t-values and statistical significance demonstrate that variable resistance training had a significant positive effect on all variables in the experimental group compared to the control group.

Results

- **Muscle Strength:** The results showed a significant increase in muscle strength in the experimental group compared to the control group. The experimental group recorded a mean difference of 20.5, with statistical significance ($p = 0.001$), indicating a strong positive effect of the training on improving muscle strength. This suggests that the training program used effectively achieved its goals in improving this variable.

- **Knee Flexibility:** The experimental group demonstrated greater improvement in knee flexibility compared to the control group, with a difference of 10.2 and statistical significance (p = 0.001). These results confirm that the training led to a significant enhancement in knee flexibility, which is essential for mobility and improving athletic performance.
- **Range of Motion:** The experimental group showed a significant improvement in range of motion, with a difference of 10.8 and statistical significance (p = 0.002). These results highlight the effectiveness of the training in increasing knee flexibility and range of motion, contributing to improved athletic performance and greater freedom of movement.
- **Dynamic Stability:** The experimental group showed an improvement of 12.3 in dynamic stability, with statistical significance (p = 0.001). This improvement reflects the experimental group's ability to perform sports movements effectively and with stability, enhancing their overall performance and reducing the risk of injuries.
- **Pain during Exercise:** The experimental group experienced a significant reduction in pain during exercise, with a decrease of 9.6 and statistical significance (p = 0.001). This suggests that the training program significantly helped in alleviating pain, improving the player's experience, and increasing their ability to consistently participate in training sessions.

Recommendations
- **Wider Application of the Training Program:** According to the results, it is encouraged to apply this training program on a wider scale, and in particular for athletes with knee pathologies. It may well form the basis of rehabilitation in athletic injuries, which could prevent further occurrences.
- **Development of Comprehensive Training Programs:** The authors recommend that a multitude training oriented programs should be initiated to target the various aspects based on strength, flexibility and the range of motion aimed at uplifting the athletic performance. Strike release training exercises that include stretches for muscle strength, flexibility, and movement should form part of the general conditioning exercise schedules of athletes.
- **Regular Monitoring of Progress:** Based on above findings, periodic assessments for athletes who have implemented similar programs should be done in order to assess their progress and consider impact of training over long-term intervals. This will enable one track the overall long-term benefits and where possible make the right changes.
- **Exploration of Other Types of Injuries:** Given that this program was used for other forms of injuries, the information gained using this program can be beneficial in determining the specificity of sports rehabilitation. They suggested that the same program should be implemented to other injuries in order to establish the effectiveness of the program for equally diverse injuries.
- **Use of Modern Techniques:** The implementation of such contemporary exercises as variable resistance training and intensive exercises inpatient could affect the rehabilitation process and enhance efficacy of physical therapy in athletes.
- **Further Research on Psychological and Emotional Effects:** More research is encouraged to establish the effects of variable resistance training on psychological and emotional health of the athletes. Furthermore, more analysis should be done on the possible long term impact of the program as to determine the pace at which the benefits would be sustained.

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