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Battery of tests for return-to-sport assessment after knee injury in athletes

Syahmirza Indra Lesmana[1,2*], Sugiyanto[1], M. Furqon Hidayatullah[1], Muchsin Doewes[1], Sinu Andhi Jusup[3]

[1]Faculty of Sports, Universitas Sebelas Maret, Surakarta, Indonesia;
[2]Faculty of Physiotherapy, Universitas Esa Unggul, Jakarta, Indonesia;
[3]Department of Physiology, Faculty of Medicine, Universitas Sebelas Maret, Surakarta, Indonesia.

*Corresponding author:
Syahmirza Indra Lesmana;
Faculty of Physiotherapy, Universitas Esa Unggul, Jakarta, Indonesia;
syahmirza.lesmana@esaunggul.ac.id

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ABSTRACT

Background: Knee injury is a common sports injury, and exercise therapy can be guided by functional and biological tests to assess healing and readiness to return to sport. This study aimed to develop a test battery to identify the most predictive functional test in determining the success of an exercise therapy program for sports injury.

Methods: A test construction methodology was used, incorporating 8 field test instruments and TGF-β1 as a biological marker. Statistical methods, including multiple correlation and Wherry Doolittle test selection, were applied to develop a functional test model supporting post-injury sports therapy.

Results: This study found no significant correlation between TGF-β1 and the single leg stance (p=0.160), single leg calf raise (p=0.902), vertical jump (p=0.344), shuttle run (p=0.794), and hop tests (p=0.555). However, significant correlations were found with the sit and reach test (p<0.001; r=0.471) and hexagonal agility test (p=0.019; r=-0.318). Multivariate linear regression showed that the single leg stance, sit and reach, and hexagonal agility tests were predictors of TGF-β1, with the single leg stance and sit and reach tests explaining 23% of its variance.

Conclusion: Test battery arrangement for functional tests that were considered predictive include single leg stance and sit and reach tests, with low correlation values, which two tests in the form of single leg balance and sit and reach tests have a relationship with tissue healing. Additionally, several other tests were designed to determine the ability of athletes to RTS.

Keywords: knee injury, return to sport test, sports injury, sports therapy.
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INTRODUCTION

Sports injury is a condition resulting from tissue damage, including bones, muscles, soft tissues, nerves, and skin caused by sports activities. It occurs during athletic activities or sports due to trauma, poor training methods, inadequate equipment, and excessive use of certain limbs.[1]

In United States, data shows a high incidence of sports injury, both in adults and children. Among the adults, a total of 1.5 million cases are recorded per year, half of which are classified as severe. Sports injury in children and adolescents are higher, with a record of 3 to 4.3 million cases per year.[2]

Athletes who suffer from sports injury often experience problems with the structure and function of the body. This disorder begins with the inflammatory phase, proliferation phase and the remodeling phase.[3] Injury-induced tissue changes can disrupt movement and function, leading to issues such as decreased muscle strength, agility, coordination, stabilization, and reaction speed. These impairments significantly affect essential sports functions, including muscle power, flexibility, stabilization, and reaction speed.

Sports injury requires proper treatment, such as the RICE (rest, ice, compression, elevation) method, from the onset.[4] This should be followed by administration of anti-inflammatory drugs when necessary. The next stage in athlete injury is rehabilitation or recovery, a process that requires collaboration between various sciences.

A physiotherapist's modality for handling athlete injury cases is through exercise therapy, which is a systematic and planned performance to restore abilities. During this therapy, athletes are retrained to perform sports movements properly and correctly after experiencing an injury. The exercise regimen is typically incorporated into a comprehensive treatment program.

The pressure to return to sport (RTS) is intense, often prompting the need for well-justified management decisions. Previously, sports medicine relied basically on clinical experience, while current practice highly depends on evidence-based methods. The increasing demand to justify management decisions and the engagement of multiple stakeholders in athlete care have led to a preference for evidence-based clinical decision-making.

To evaluate the ability of athletes to RTS, predictive tests are essential. Currently, there is no consensus in the literature regarding RTS decisions given the lack of standardization and objective criteria. It is important to acknowledge that recommendations for determining RTS remain unclear, with a primary focus on full ROM, strength, and functional ability without complaints.[5]

Meniscus injury can arise from both traumatic and non-traumatic causes. Non-traumatic injury typically affects middle-aged and elderly adults and is often related to degenerative processes such as osteoarthritis. Meanwhile, traumatic injuries are more common among young people and are related to sports activities such as football, basketball, skiing, and baseball. Its mechanism is usually related to knee movements including twisting, cutting, hyperextension, or excessive force. Meniscus injury is associated with anterior cruciate ligament injury, occurring in over 80% of cases.[6]

Therapeutic exercise is the systematic, planned performance of bodily movements, postures or physical activities intended to provide a patient/client specifically given to patients to treat musculoskeletal pain conditions.[7,8] Exercise therapy programs often rely on a single type of functional test. As a result, the best predictor of the success of post-injury rehabilitation remains unknown. Biological tests, such as Transforming growth factor beta (TGF-β). Previous studies on animal's model showed that there was an increase on TGF-β levels and a significant relationship to tissue repair.[9] TGF-β test is accurate to describe the biological condition because using blood as a sample. These tests are correlated with functional assessments that are accessible and cost-effective, facilitating the prediction of tissue repair. This study aimed to develop a test battery on functional tests as a predictor of the success of exercise therapy programs in post-sports injury.

METHODS

The study evaluated the validity of several field tests conducted at the Jakarta Sports Physiotherapy Clinic. Battery combination testing was conducted by comparing the results of functional tests with the criteria provided by the biological indicator TGF-β1, using multiple correlations. This study has been approved by Health Reseach Ethics Comitte Dr. Moewardi General Hospital Number 2.785/XII/HREC/2024. Total samples are 54 participants, were selected through a purposive random sampling technique. Inclusion criteria were male and female aged 13 – 40 years, who suffered first sport injury on the lower extremities for 4 months in the last 1 year, no consume supplements/anti-inflammatory drugs and smoking, normal BMI and sign informed consent. Exclusion criteria were having acute or chronic diseases, consuming alcohol/drugs, spinal disorders/injuries.

The study adopted a test construction methodology which includes: a. Test instrument developed as a tool to determine the success of a post-injury knee sports exercise therapy program. The development aimed to establish criteria for evaluating the effectiveness of post-traumatic exercise therapy programs. b. needs analysis was conducted to identify problems arising after injury and the bio-motoric elements that influence the performance of athletes. Data collection on test elements was conducted through observations and expert input from journal literature studies. Eight test instruments were recommended as part of the functional test battery to access post-traumatic exercise therapy. These include jump, one-legged balance, one-legged squat, vertical jump, flexibility, Y balance, shuttle run, and hexagonal tests. To be used as a measuring instrument, it was necessary to meet the validity and reliability criteria. Construction validity was crucial exemplified by the vertical jump test, which measures the explosive strength of muscles. Similar validity tests were applied to other selected test questions. Additionally, reliability was assessed using the test-retest method and the complete variable correlation method. For differential power, a normality test was conducted using the Lilliefors method.

The selection of field tests to be used as functional test instruments is guided by statistical methods and scientific principles. This process includes creating a functional test model for the success of exercise therapy programs. The first step in compiling a series of tests is to determine the correlation coefficient of each test item. The results of the series of trials led to the development of new instruments with valid construction. After validation, these instruments were used as data collection tools for re-evaluating post-injury sports performance.

The study began with a preliminary examination to determine sports injury through assessment, enabling accurate diagnosis. Participants were subjected to a therapy exercise program 3 times a week for 4 months routinely and regularly, followed by testing to determine the ability to RTS. The assessment comprised 8 types of functional tests and 1 laboratory test for biological indicators.

This study conducted a multiple correlation test to examine a dependent variable (criterion) with 8 independent variables (predictable). The Wherry Doulittle test selection method was used to obtain a multiple correlation coefficient for sports skill tests composed of several experimental test elements. Wherry Doulittle test selection method is one of the statistical analysis techniques to obtain multiple correlation coefficients of sports skill tests consisting of several experimental test items.

RESULTS

Table 1 presents the sample characteristics, showing an average age was 24.19 years, with ages ranging from 13 to 40 years. For weight and height, the averages were 71.65 kg for weight and 170.65 cm, respectively. The average Body Mass Index (BMI) of 24.79. Additionally, the average duration of injury was 8.04 months, and both blood sugar and Hb were within normal limits.

The majority of the gender were male with a total of 40 people or 76.9%. All participants were actively engaged in regular sports activities, with soccer being the most common sport (46.2%). Running and volleyball were the least common and each was performed by 3.8% of the participants. All injuries were localized to the knee area, and the most common was Anterior cruciate ligament (ACL) disorders experienced by 50% of the samples. It was important to acknowledge that 18 people or 34.6% experienced knee disc injury.

Table 2 shows the results of the bivariate analysis, indicating that the sit and reach test and hexagonal test had a significant correlation with TGF-β1 ($p< 0.05$). In contrast, the single leg stance, single leg calf raises, vertical jump, shuttle run, and hop tests showed no significant correlation with TGF-β1 ($p> 0.05$).

Single leg stance, sit and reach test dan hexagonal agility test were qualified for

Table 1. Characteristics of 54 subjects

Characteristics	Mean±SD	Median	Minimum	Maximum
Age, year	24.19±6.06	-	13	40
Weight, kg	71.65±13.56	73	50	118
Height, cm	170.65±7.82	172	155	182
BMI, kg/m²	24.7±5.34	24.71	20.8	35.6
Injury time, month	8.04±3.16	7	3	16
Glucose	80±20.20	-	46	143
Haemoglobin	15.04±1.46	-	11.6	17.3

BMI, body mass index; cm, centimeter; kg, kilograms; kg/m², kilograms per square meter; SD, standard deviation

Table 2. Bivariate analysis between functional test with level of transforming growth factor beta 1 (TGF-β1)

Functional test	Level of TGF-β1		
	N	*P*-value	*r*
Single leg stance	54	0.160	0.194
Single leg calf raise	54	0.902	0.017
Sit and reach test	54	<0.001	0.471
Vertical jump	54	0.344	-0.131
Hexagonal test	54	0.019	-0.318
Shuttle run	54	0.794	-0.036
Hop test	54	0.555	-0.082

N, number of subjects

Table 3. Multivariate linear regression test with level of transforming growth factor beta 1 (TGF-β1)

Variable	B	*P*-value	*r*
Sit and reach test	1.429	0.001	0.43
Single leg stance test	0.040	0.032	0.27
Constanta	44.013		

B, beta coefficient; r, correlation coefficient

multivariate linear regression test (p<0,25) as predictors to relate with TGF-β1 value. The most significant and related to TGF-β1 is the sit and reach test (p=0.001) and the second is single leg balance (p=0.032). The result of the multivariate linear regression test can be seen on Table 3. Single leg stance and sit and reach together can influence TGF beta1 levels in the body by 23%.

DISCUSSION

Athletes experience injury, specifically in the lower leg, a rehabilitation process is needed for recovery. Subsequently, tests should be conducted to determine the ability of athletes to RTS. So far, the RTS that has been carried out only looks at the functional ability of athletes and has not been linked to the tissue healing process.

In this study, several forms of tests have been carried out that can be used as a measure to determine the return of injured athletes. The sample consisted of 54 athletes diagnosed with lower extremity by a doctor. Among the 54 samples, 26 experienced ACL injury, which is in line with the demographic data from the United States, where the annual rate is 60 per 100,000 people, totaling over 200,000 cases each year. It was important to acknowledge that 46.2% and 19.8% of the total sample played soccer and basketball, respectively.

Based on the results of testing conducted on 54 samples for one-legged movements, an average time of 105.6 seconds was recorded, signifying normal conditions. The hexagonal test results showed an average value of 4.59 seconds and were classified under the flat category according to Dr. Adiamika's Practical MK textbook. The shuttle run test had an average value of 11.28 seconds, which is a very good category. For the hop test, the average value was 97.32%, with normal values exceeding 95%, signifying that all samples met the established standard.

The descriptive test analysis showed that all participants followed a recovery exercise program right after experiencing an injury. As a result, the requirements for statistical analysis tests to determine the relationship between independent and dependent variables were met. Participants have followed a post-traumatic lower limb rehabilitation exercise therapy program which met evidence-based requirements. The program comprised 4 phases and was conducted over a certain time, leading to an average TGF value of 68.90 ng/ml. This value shows that there has been a healing process in the collagen proliferation and regeneration process. In accordance with a study conducted by Pradita Wulandari, an increase was observed from day 5 to 21 when measuring TGF-β1 levels.[10]

The result is in line with the hypothesis that an increase in TGF- levels was observed during the wound-healing phase. The study showed that participants were subjected to a tissue healing process despite the variation in the TGF- levels due to differences in injury type and the sampling times. In cases of anterior cruciate ligament reconstruction, the biological and mechanical healing of intra-articular tissue typically takes approximately 6 months. In this study, blood sampling for tgf-beta examination was collected before 6 months after reconstruction. While the healing process has not reached its maximum condition, tissue proliferation and regeneration are evident, signifying progress. For meniscus injury, the tissue healing process enabling RTS was between 12 to 16 weeks or equivalent to 3 to 4 months. At this stage, the meniscus sufficiently recovered to resume normal function. Differences in

tissue injury can result in varying healing times, but the tissue healing process is evident in the TGF value observed.

Based on the correlation test between variables, only the sit and reach test (p<0.000) and the hexagonal test (p=0.019) had a significant relationship with the beta. This condition shows that the other six tests were not related to beta TGF and, hence, cannot describe tissue healing. Despite test results not showing any correlation, the descriptions of all tests performed reflect good performance. This signifies the possibility of obtaining good test scores without a correlation between tissue conditions and the healing process of the sample. The report is reinforced by a study conducted by Ichiro Sekiya, MD, and colleagues who stated that there was no correlation between test results and anterior knee weakness.[11] According to an investigation, vertical jump ability did not show a decrease in the risk of post-accident osteoarthritis with a 9-month recovery program.

A study stated that the slower backward running times observed in freshmen with a history of lower extremity injury might reflect either inadequate care received at the high school level or the benefits of a mandatory core strengthening program for a returning athlete. Several studies have shown that functional tests have no relationship with the tissue healing process. Based on the correlation test of independent variables with TGF beta 1 levels, only the single leg Stance, the sit and reach, as well as the hexagonal tests were included in the multivariate linear regression analysis due to a p-value <0.25.[12]

All participants in this study were included in the exercise therapy program in order to recover from sports injury. Following the exercises, functional tests were conducted and good results were obtained. This means that the therapy given has been completed by the well-performed participants. Based on the TGF beta 1 test, the tissue remains unrecovered compared to before injury. This is shown by the very weak correlation between functional tests performed and the TGF beta 1 values obtained. From the results of the bivariate tests, only 3 functional tests had a significant correlation with the TGF beta value. Despite functional tests being passed by the average sample, good tissue healing was not observed.[13,14]

The insignificant correlation between functional test scores and Beta 1 TGF signified that athletes with incomplete tissue healing can still perform sports activities effectively. This condition has a high chance of occurrence because the exercise therapy program focuses on building muscle at the beginning of sports activities. When an injury occurs in muscle tissue, strong muscles can compensate temporarily for the injured area. In cases where the muscle weakens and there is a decrease in function, the partially healed injury may be further stressed increasing the risk of reoccurrence.[15] It is necessary to pay attention to the long-term effects of continuing sports activities before full recovery. Studies have shown that early degeneration occurs more quickly in athletes with prior injury. For instance, athletes subjected to anterior cruciate ligament reconstruction often develop traumatic arthritis or experience a faster bone damage process within 15 years.

The inclusion of a biological dimension in Return to Sport (RTS) evaluations such as using the TGF-β1 biomarker is an innovative approach that enhances the accuracy of assessing post-injury tissue readiness.[16,17] This study found that the sit and reach test and single leg stance test had significant correlations with TGF-β1 levels, indicating a link between flexibility and balance with tissue healing processes. This aligns with recent findings showing that muscle flexibility and joint stability contribute to improved collagen regeneration and tissue remodeling after ligament or meniscus injuries. Therefore, integrating functional tests with biological biomarkers may offer a more holistic approach to RTS decision-making.[18]

Although some functional tests demonstrated good performance results, not all were correlated with tissue healing status as indicated by TGF-β1 levels. This finding suggests that athletes can perform well functionally even if the biological healing process has not been fully optimized. A study also found that high functional test scores do not always guarantee structural tissue integrity, thus increasing the risk of reinjury. As such, the use of biological indicators like TGF-β1 is essential as an additional validation tool to ensure athletes are not only functionally ready but also biologically recovered before returning to full sports activity.[19]

The discrepancy between functional test results and biomarker levels may be influenced by individual differences in healing metabolism, compliance with rehabilitation programs, and prior training loads.[20] This study suggests that the sit and reach test has the highest predictive value, which is consistent with recent literature showing that lower limb flexibility is positively associated with tissue healing biomarkers. A combination of balance, flexibility, and agility tests should be considered the minimum parameters for comprehensively assessing RTS readiness. Thus, a multidimensional approach combining functional tests and biological biomarkers is increasingly important in modern sports physiotherapy practice.

This study has several limitations that need to be improved in further research. First, samples were taken from all forms of knee injuries and were not specified for a particular type of injury. Each tissue has a different healing time so that the time of data collection can indicate that tissue healing has occurred, but some have not experienced tissue healing. Second, the range of sample's age too wide. Third, researchers couldn't control other factors that can affect the tissue healing process such as nutritional intake, activities of injured athletes, other medical procedures outside the program that has been given.

CONCLUSION

In conclusion, there was a significant relationship between the Sit and reach as well as the Single-leg stance tests with TGF Beta 1. The results of the correlation test of the independent variables with TGF level beta 1 show that only the single-leg stance test, as well as the sit and reach test, were used as predictors for tissue healing.

ETHICAL CONSIDERATION

This study protocol was approved by the Health Reseach Ethics Comitte Dr. Moewardi General Hospital Number 2.785/XII/HREC/2024 and all the participants had signed the informed consent.

CONFLICT OF INTEREST

The entire research process was conducted independently and there is no conflict of interest with the parties involved in this research.

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AUTHOR CONTRIBUTIONS

SIL contributed to writing ideas, designed the research, collecting and analyzing data and wrote the manuscript; SG and MFH contributed to analyse the problems, concepted the study design and methodology; MD and SAJ contributed to searched the literature and reviewed the manuscript.

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