

体重支持指数1.2の回復を目標としたアスレティック・リハビリテーションの
効果に関する実践研究
－膝関節靭帯損傷を負った柔道選手を対象として－

A practical study about effect of athletic rehabilitation with the goal of
1.2 of the weight bearing index
－ with Judoists with knee ligament injury as subjects －

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要 旨

本研究の目的は、体重支持指数1.2の回復を目標としたアスレティック・リハビリテーションの有効性を実証するために、膝関節靭帯損傷を負った柔道選手12名を対象にアスレティック・リハビリテーション・プログラムを実践し、その回復効果を明らかにするとともに、得られた結果を先行研究の結果と比較検討することである。

アスレティック・リハビリテーションの実践は1997年からである。対象者の年齢は、15歳から26歳（高校生3例、大学生8例、社会人1例）であり、平均年齢19.3歳であった。リハビリテーションの評価としては、筋力評価（WBI1.2）、機能評価（ROMおよびMMT）、大腿部周径値、体脂肪率などを測定した。分析はSPSS9.0J for Windowsにより、 χ^2 検定およびt検定を行った。その結果、以下の点が明らかとなった。

- 1) 今回実践したアスレティック・リハビリテーションの回復効果を重傷度別にみると、筋力回復は重症度が重い場合により日数を要した。WBI改善の差異については、重症度第Ⅱ度の群において、プロジェクト前半に比べ後半により改善の変化が大きく、個人差も大きかった。機能回復はプロジェクトの初期において、重傷度第Ⅱ度群の方が第Ⅲ度群に比べ回復が良かった。
- 2) 今回実践したアスレティック・リハビリテーションは、先行研究の結果と比較して、筋力および機能回復に有意に優れていた。また、本プログラムは重症度に関係なく、患側の大腿部周径値、体脂肪率、さらに競技復帰の大きな課題である後遺症や再発不安の解消にも有効であった。

これらの結果から、今回実践したアスレティック・リハビリテーションは、身体のみならず精神的な側面からも選手をサポートできる優れた方法であるといえる。今後、アスレティック・リハビリテーションを周知、普及することが、膝関節に損傷を負った選手への対策が十分に考えられていない日本の現状では、非常に有用であるといえる。

キーワード：アスレティック・リハビリテーション、柔道選手、膝関節靭帯損傷

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Abstract

The purpose of this study was to verify the effectiveness of athletic rehabilitation with a weight bearing index of 1.2 as the minimum recovery goal. Namely, we conducted our new athletic rehabilitation program on 12 Judo athletes with knee ligament injuries and determined the degree of their recovery, and we also compares the results obtained in the present study with those from the preceding studies.

We have conducted athletic rehabilitation since 1997. Subjects examined in the present study ranged from 15 to 26 years in age (three high school students, eight college students, and one full-time worker), with a mean of 19.3 years. Muscle strength (WBI 1.2), functional performances (ROM and MMT), femoral circumference, body fat rate, etc. were measured as items used to evaluate the effectiveness of rehabilitation. The data obtained were analyzed with a χ^2 -test and a t test using SPSS 9.0J for Windows. As a result, the following points were clarified:

1) When the effect of the athletic rehabilitation in relieving from knee ligament injury was analyzed by severities of injuries, it was found that muscle strength required a longer period of time for recovery as the injury was severer. As for differences in WBI recovery, there was a greater variation in improvement and greater interindividual differences in the group of severity grade II subjects in the second half of the project, compared with those observed in the first half. Functional recovery in the early stage of the project was better in the group of severity grade II subjects than in the group of severity grade III subjects.

2) The athletic rehabilitation conducted in the present study provided significantly better outcomes of muscle strength and functional recovery, as compared with those seen in the preceding studies. Irrespective of severities of injuries, this program was also effective for the increase in femoral circumference on the affected side, the decrease in body fat rate, and resolution of concern about sequelae and recurrence, which is a serious problem interferes with return to competitions.

These results indicate that the athletic rehabilitation conducted in the present study is an excellent procedure that can support injured athletes not only in physical aspects, but also in mental aspects. In the future, it is extremely important that this program should be made more aware and wider utilization in Japan because proper consideration has not been given to athletes with knee injuries.

Key words: athletic rehabilitation, judo players, knee ligament injuries

Introduction

Judo is contact sports with frequent use of foot and leg techniques, placing great stress on the knee joint. Because of this, knee injuries/disorders often occur in judo, and knee ligament injuries are statistically determined to most often occur in judo among knee injuries¹⁾.

However, measures against these injuries are now limited to medical treatment (medical rehabilitation), even for sports players, as with for the generality of people. However, the final goal of rehabilitation for sports players is the return to competition without anxiety about after-troubles or recurrence, requiring restoration of muscle strength, endurance, speed, power, etc. at a higher level.

Thus we drew up a rehabilitation program covering the entire course of recovery from injury to the return to competition for injured sports players, and we proposed to designate the execution of this program as athletic rehabilitation. To determine the effects of this program, we organized an athletic rehabilitation project team, composed of a sports doctor, a manager, a physical therapist, a judo therapist, a dietitian, and a clinical psychologist, and we attempted to conduct the program with the team to rehabilitate 12 judo players with knee ligament injuries.

The purpose of this study is to verify the effectiveness of athletic rehabilitation with a weight bearing index of 1.2 as the minimum recovery goal. Namely, we conducted our new athletic rehabilitation program on 12 Judo athletes with knee ligament injuries and determined the degree of their recovery, and we also compares the results obtained in the present study with those from the preceding studies.

Methods

Subjects

Twelve judo players who were diagnosed by an orthopedic surgeon as having a judo-related grade II (moderate) or severer knee ligament injury (grade II and grade III injuries in 6 players each) at the outpatient clinic of the orthopedic surgery department of university A or B hospital or general hospital C were entered into the study. The athletic rehabilitation program was drawn up to evaluate its practicality in the judo players. Age at injury ranged from 15 to 26 years (3 high school students, 8 college students, and 1 full-time worker), with a mean of 19.3 years.

Duration of the Rehabilitation

We started conducting the athletic rehabilitation around 1997. Timing of initiation and termination of the rehabilitation differed among judo players.

Procedure

1. Role of the project team

The project team having the following composition was organized to carry out the athletic rehabilitation (fig.1). Although the athletic trainer would have a particularly important role in the practice of this program among the program team members, the athletic trainer who participates in co-medical activities has not been approved in Japan. Thus, the physical therapist and the judo therapist substituted for the athletic trainer as they mediated between the sports doctor and the judo player and also cooperated closely with the trainer.

Dietitian managed the athlete's eating habits. Specifically, they conducted the following. In their management of eating habits, the athletes kept in mind favorably balanced meals and were

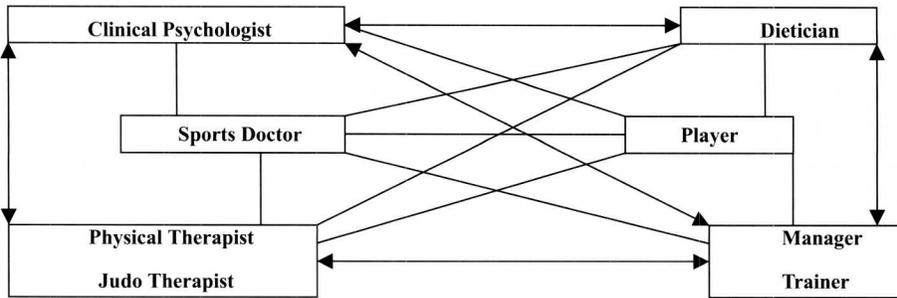


Fig.1 The project team of athletic rehabilitation in this practice

instructed to conduct the following thoroughly (When ordinary eating habits were favorable, the intake of supplements was not necessary and was not recommended specifically).

- Ensure the taking of three meals a day at predetermined times.
- Have meals with all food groups.
- Have fruits and vegetables each time and several kinds daily.
- Maintain a water intake exceeding the amount sweated out
- In meals from the first stage to the second stage, the average calories were limited to about 2000Kcal daily, although it depended on body size. However, the amount of each meal increased in accordance with any increases in the amount of training.
- When the end of the second stage was reached, the thickness of the affected thigh became conspicuously thinner than the other non-affected one. This was mainly due to muscular weakness, and it was thus kept in mind to strengthen the muscle through nutrition.

Clinical psychologist took charge of mental support for the athletes after their injury from the specialized aspects of being different from the supervisors and team trainers. In conventional rehabilitation (medical rehabilitation), clinical psychologist were not included among the support staff. However, the

mental shock to an athlete after an injury is beyond our imagination. The athletes themselves are aware that disorders of the knee joints are potentially career ending, especially for Judo athletes, and their anxiety knowing that they may not be able to continue Judo must be unbearable. Clinical psychologists attempt to dispel such anxiety and concerns about the athletic rehabilitation and to provide mental support for the athletes to return to Judo smoothly, while being in close cooperation with the physicians in charge and the trainers.

2. Evaluation criteria for rehabilitation

1) Evaluation of muscle strength

Although an 80-90% restoration of sports performance is generally considered as a yardstick for the return to sports activities for injured sports players, such recovery may be at the risk of recurrence and after-troubles in the contract sports judo. Therefore, a weight bearing index (WBI) of 1.2 was used as a yardstick for the return to judo activities in the athletic rehabilitation evaluated in the present study.

The WBI is used to evaluate leg muscle strength and expressed as the following equation. This index is useful for the evaluation of muscle strength in sports players with knee ligament injuries^{2,5)}. In this practical study, the rehabilitation program was drawn up as a 5-step

course. Step 4 was considered to be accomplished when a WBI of 1.0 (100%) or more was obtained, and step 5 was accomplished, namely, the athletic rehabilitation program was completed in other words, when a WBI of 1.2 (120%) or more was obtained (Table.1).

2) Evaluation of function

In function evaluation, the range of motion (ROM) and the manual muscle strength test value were used as figures expressing the degree of recovery with rehabilitation. In ROM testing, the lower extremity was bending in the direction to the buttock in a prone position, and the angle until a pain was felt was measured.

Functional evaluation methods used were the range of motion (ROM) test and the manual muscle test (MMT) for numerical values to confirm the recovery by the rehabilitation.

When a joint injured, pain occurs with joint

movement. The soft tissues of the joint are consisted of contractile and non-contractile objects. The ligament is non-contractile. Thus, when the ligament injured, a pain is felt when a force is added in the extension direction. In the ROM test, the foot is bended to the hip direction under a procumbent condition and an angle until a pain is felt is measured. The case conducted by self is called active-range of motion (AROM), and the case conducted by other person is called passive range of motion (PROM). These measured values become indices to confirm the recovery by the rehabilitation. Tables 2 and 3 show the summaries.

3) Femoral circumference

When an athlete stops training and exercising unexpectedly and takes time off, muscle strength conspicuously becomes weak. There is a data in which the weakness reaches 10% one

Expression of the weight-bearing index (WBI)

$$\text{WBI} = \text{maximum isometric knee extension force (kg)} / \text{body weight (kg)}$$

Table.1 WBI values and corresponding evaluation results

WBI	
Less than 0.4	Gait disorder is present.
0.4 ~ 0.6	Able to walk, but difficult to do everyday activities which are accompanied by pain.
0.6 ~ 0.8	Able to do everyday activities without difficulty, but easy to be fatigued and unable to take up a drastic motion in sports.
0.8 ~ 1.0	Able to play sports for pleasure, but with physical and mental concern.
1.0 ~ 1.2	Able to actively participate in all activities with almost no fear of health.
1.2 or more	Level of top-class sports players.

Table.2 ROM values and corresponding evaluation results

ROM	
Less than 120°	Difficulty in playing a professional sports game.
120° ~ 130°	No difficulty in playing a professional sports game, although the ROM does not reach the same level as that on the non-affected side.
130° or more	The ROM on the affected side is equal or superior to that on the non-affected side.

week after an injury. Thus, the femoral circumference at 10cm above the affected knee was measured. The effects of the rehabilitation were clarified by comparing the femoral circumference on the affected side with that on the non-affected side.

4) Body fat level

In the project team, the dieticians took charge of the management of their eating habits, stressing management of their body weight. Although athletes tend to become overweight during the rehabilitation period, management of their body weight is important for them to return to their sport. Thus, the dieticians conducted the management of their body weight with the body fat level and obesity degree as indices, and supported the increase of their physical strength from nutritional aspects. Although the body mass index ($\text{kg}/\text{m}^2 = \text{body weight (kg)} \div \text{height (m)}^2$) is used as one of the indices expressing the obesity degree, this index indicates the obesity degree based on total body weight, which is not so applicable to Judo athletes. The athletes for heavy weight classes

have apparently excessive weights, but are not obese.

The following table shows a comparison of the mean body fat levels between the general population and athletes (Table.4).

5) Actual practice of the athletic rehabilitation program

In carrying out the athletic rehabilitation, the athletic rehabilitation program in which the whole period from immediately after injury to return to the competition was divided into five steps was made with the references by Koyama⁶⁾, Southmaid and Hoffman⁷⁾ (Table.5). The trainings in the program were referred to those by Kuriyama et al⁸⁾, and the warming up and stretch were referred to those by Fujiwara et al. ⁹⁾. The program was proceeded according to health and injury conditions in each subject. The outline of the athletic rehabilitation program conducted in this study is shown in Table.5.

1) The first step

In this step, regardless of the severity of

Table.3 Evaluation criteria for manual muscle testing

Manual muscle testing	
0	Unable to touch muscular constriction.
1	Able to touch muscular constriction, but no joint motion.
2	Unable to resist gravity, but able to move in the full range of motion if the effect of gravity is removed.
3	Unable to conquer resistance, but able to move in the full range of motion against gravity.
4	Able to conquer weak resistance.
5	Normal, able to conquer strong resistance.

Table.4 Comparison of the body fat levels between the general population and athletes

	Males (%)	Females (%)
General population	12~15	20~25
Athletes	8~12	10~12

injuries, all subjects received appropriate diagnoses and 48-hour I.C.E.S.R treatment. I (Ice) indicates the cooling of affected sites with ice, which causes to contract small vessels, inhibit internal bleeding, lower fever, and alleviate pain by acting on the peripheral nerves. C (Compression) means to compress by stretching bandage, by which the edge and edge of the injuring ligament approach each other to minimize internal bleeding and formation of hematoma. E (Elevation) indicates the elevation of the affected ligament to a position higher than the heart. S (support stabilization) indicates supporting and fixing of the affected sites. R (Rest) means to rest the affected sites. However, athletic rehabilitation aiming at the return to competition has already started from the time immediately after the injury. Especially, when athletes stop exercising and take time off unexpectedly, muscle strength decreases rapidly. There is data suggesting that the decrease in muscle strength reaches 10% one week after injury. Thus, during this period, while subjects with grade II used crutches and were fixed with a plastic cast, they received training for isometric movements which was conducted without bending the knee in bed and training for other non-affected sites to prevent the reduction of muscle strength. However, these trainings were conducted within a range at which the subjects didn't feel pain. Although

it is likely for the subjects to take rests during this step in the medical rehabilitation, trainings in bed were conducted actively.

Because some anxiety remained after the plaster cast was removed, the injured site was supported by taping. For subjects with grade II, when necessary, taping was done during the rehabilitation even after the second step and trainings were then conducted¹⁰⁾.

2) The second step

In the second step, before they shifted from walking with crutches to ordinary walking, walking in water was adopted. When the use of crutches is stopped in order to proceed to ordinary walking, a subject becomes anxious about putting a load on the affected site and feels very uneasy. When the walking in water training is conducted during the mid-term, it can be expected that they can shift to ordinary walking smoothly and the trainings can also be promoted. The recovery of blood circulation was attempted by removing fatigued substances through conducting training by walking with a load, bathing in warm water, and by massages.

Next, after pain was alleviated and the affected site became stable, thermotherapy was conducted. Thermotherapy includes simple methods such as soaking in hot water and using a hot towel, bathing with paraffin, ultrasound, pads heated by an electric heater, and a far-

Table.5 Athletic rehabilitation program conducted in the present study

Step	
1	Treatment with ice, compression, elevation, support-stabilization, and rest (I.C.E.S.R.), immobilization with a plaster cast, isometric movements, and preparation of SOAP NOTE.
2	Water walking, weight-bearing walking, warm water bathing, massage, and exercises to extend the range of motion (isometric contraction training for muscles of the thigh and gluteal region).
3	Full weight-bearing walking, jogging, stretching, muscle training/resistance exercises (isotonic muscle training for the quadriceps, muscles of the gluteal region, and hamstrings).
4	Function training (isokinetic and endurance training).
5	Professional training (complexity training).

infrared lamp. Because no significant difference in the effect among these methods is evident, the subject was allowed to select one which he/she felt most comfortable with and that method was used. Table.6 shows the effects.

Moreover, from the later half of this step, the weight was limited to 30% and muscular trainings were conducted to the extent that swelling and pain didn't occur, including leg presses, leg extensions, leg curls, and half squats. As such, the femoral quadriceps muscle and hamstrings and gluteus maximus muscle were strengthened. Next, a case of the training regime of leg presses and leg curls is shown (Table.7). These trainings were continued subsequently as the load was increased gradually until all programs were completed.

In addition, although stretching was included before and after the trainings from this step, because a great tension is loaded on the ligament of the knee joint at the time of excessive extensions, the stretching at the initial stage was limited to simple ones. Specifically, in a procumbent position, the subject bent the affected leg in such a manner that the heel

touched the hip for 20 seconds each time.

3) The third step

In the third step, the training started with relatively low-load exercises such as using a bicycle ergometer, followed by walking and mild jogging for complete-load walking. A training for muscle strength was conducted, using an isokinetic machine, and aimed at achieving a WBI of 0.8 or more. This numerical value is the final goal for medical rehabilitation and is regarded as a standard for a return to competitive sports.

Although isometric movements not to hurt the affected site any further were stressed in the previous steps, in this step, improvement of the range of joint motion became the new goal.

To improve the range of motion, the following are necessary: (1) an improvement blood circulation and an increase in the elasticity of the connective tissues of the muscles and joints, (2) the alleviation of muscular tension, and (3) an enhancement of the cooperativity among muscle groups.

Thus, from this step, we executed the

Table.6 Thermotherapy and its effects¹¹⁾

Treatment methods	Warmed tissues	Depth
Bathing with paraffin	Skin	Shallow
Treatment with water (bathing with an eddy current)	Subcutaneous tissue	↓
Far-infrared rays	Subcutaneous tissue	↓
Ultrasound	Selective muscular warming	↓
Extreme ultrasound		↓
Ultrasound	Tendon, ligament, nerve, joint, muscle/fascia	↓ Deep

Table.7 The training regime of leg presses and leg curls

Intensity of leg press		Intensity of leg curls	
Weight	30%	Weight	30%
Repetitions	20 reps	Repetitions	20 reps
Set number	Three sets	Set number	Three sets
Break	One minute between sets	Break	One minute between sets

* Four-minute break between exercises

following stretches, which have high effects on training muscular flexibility and cooperativity.

(1) Stretching of the femoral quadriceps muscle

In a procumbent position, both knees are raised and a force is added to the femoral part to extend the knee. A partner holds the ankle and stops the subject from extending the knee.

(2) Stretching of the gluteus maximus muscle and hamstrings

In a sitting position, the subject holds their hands on their back and bends backward. A partner stretches the elbows and presses the back with both hands. With both legs spread open and both hands held out in the front of the body, the two pull each other.

The training regime for leg presses and leg curls at this step was as follows (Table.8).

4) The fourth step

In conventional medical training, the rehabilitation is completed in the previous step (the third step) and subsequently, the subject continues training and returns to competing. However, in athletic rehabilitation, from this step, training aimed at a competitive return begins actively. Muscle strength training with increased loads and systemic power-ups using

dumbbells and barbells are included. The training regime becomes diverse, including full-power running and exercises for actual competitions. At this step, because the subject may become mentally unstable and feel anxiety, support by the clinical psychologists is important.

In the fourth step, training for strengthening the instantaneous force was conducted, and the achievement of WBI 1.0 or more, was the goal, which is necessary for minimum competitive action from the viewpoint of the WBI loading level in the femoral quadriceps muscle. In addition to jogging, full-power running was also conducted. Moreover, exercises simulating movements in Judo were conducted and how the ability of muscle strength and function necessary for competition recovers was confirmed. The training regime of leg presses and leg curls was as follows (table 9).

5) The fifth step

In the fifth step, specialized training related to competition, such as driving and set up were conducted. To strengthen the muscles, the training amount was reduced to 3-5 sets with 2-4 reps per set at a high load (90%-95%). The break

Table.8 The training regime of leg presses and leg curls

Intensity of leg press		Intensity of leg curls	
Weight	40%	Weight	40%
Repetitions	20 reps	Repetitions	20 reps
Set number	Three sets	Set number	Three sets
Break	One minute between sets	Break	One minute between sets

* Four-minute break between exercises

Table.9 The training regime of leg presses and leg curls

Intensity of leg press		Intensity of leg curls	
Weight	40%	Weight	50%
Repetitions	20 reps	Repetitions	15 reps
Set number	Three sets	Set number	Three sets
Break	One minute between sets	Break	1.5 minute between sets

* Four-minute break between exercises

between sets was prolonged to five minutes. A WBI 1.2 of the affected side, the final goal for a return to competition, was aimed for. Training to maintain strong muscle strength and physical strength in sites other than the injured sites as well as the rehabilitation of the affected site, is necessary. For this reason, further power-ups using dumbbells and barbells were aimed at continuously after the previous step.

They also received support for mental reinforcement, such as the will to return to competition and maintenance of this interest. They made individual subjects recall the situation under which they were injured and carefully and repeatedly investigated what actions are necessary to avoid it happening again.

Moreover, after a subject returned to competition, information was exchanged closely among the supervisors, trainers and subjects, and their follow-ups were conducted thoroughly to prevent its recurrence and sequela.

Statistic methods

The data obtained were analyzed with a (2-test and a t test using SPSS 9.0J for Windows. Statistic methods used are indicated in the results and discussion section A of the text. At that time, a 5% level and a 1% level were evaluated as being statistically significant.

Results and Discussion

1. Results in the different steps

1) The first step

In this step, 48-hour I.C.E.S.R treatment, isometric training without bending the knee in bed and training for other non-affected sites were conducted. The peak swelling of the affected site was observed mostly on day 2 after the injury, and this sign was more apparent in subjects with a more severe condition. Because of the use of crutches, some subjects had edema

or numbness in the affected leg.

2) The second step

In subjects with grade II, the use of crutches was stopped and walking training using a pool with warm water was conducted and then walking with a complete load was conducted. When the use of crutches was stopped, the subjects had similar complaints about their anxiety. However, the load decreased once they entered the pool and they could walk with both feet, leading to an air of confidence. It was recognized again that the effects of walking in water are great.

Subjects with grade III were similarly treated. However, their time came about two weeks later than that in the subjects with grade II. In addition, although the subjects with grade III underwent surgery, because surgery is impossible until the swelling of the affected site is alleviated, trainings were conducted very carefully to prevent any reduction of muscle strength during this period. A physician in charge determined that the surgery would be performed 2-3 months after the injury.

Thermotherapy conducted between muscular trainings was very effective for alleviating muscular tension. The subjects especially preferred therapy with far-infrared rays.

During this period, because the subjects knew specific numerical goals for their rehabilitation, as well as the situation regarding muscle strength and ROM, they showed their willingness to seriously wrestle with the rehabilitation.

3) The third step

WBI testing was conducted only on subjects with grade II. The results are shown in Table.10.

In conventional rehabilitation (medical rehabilitation), generally, when attaining the goals of "a WBI 80% or more for the affected

leg" or "a difference in muscle strength of 90% or less between the non-affected side and the affected side", the return to competitive sports has been achieved.

Applying this condition to the measured results in this study, five out of six subjects exceed this condition. According to the standard of medical rehabilitation, the five subjects would take the course that, as when rehabilitation at a hospital is completed, they may conduct rehabilitation by themselves and ultimately return to sports. On the other hand, in athletic rehabilitation, to prevent sequela and injury recurrence, it aims at strengthening the affected muscle strength to a level stronger than the previous healthy muscle strength. Especially, in fighting competitions such as Judo, it is difficult for the athletes to demonstrate their actual abilities sufficiently if they have anxiety over a recurrence. In fact, there have been many subjects who have had a recurrence, and it is thus required to elevate their conditioning above this hurdle for the return to sports. In the athletic rehabilitation attempted in this study, attaining a WBI 1.2 or more was the goal for a

return to Judo, and all subjects actually started the athletic rehabilitation with this level.

The six subjects with grade III (including complications) underwent reconstruction of the anterior cruciate ligament when they entered the third step. After they took the roughly 50-day course with postoperative rest, use of crutches, walking in water, and training for muscle strength, they shifted to the rehabilitation of the fourth step.

From the third step, jogging was conducted with a standard distance with which they didn't become tired. Table.11 shows the results of all subjects who jogged similar distances. Despite any previous training for leg strength on an aerobike, the distance that they could jog was short and the difference between indoor training using a machine and actual running was clearly observed. However, the distance increased over time.

4) The fourth step

From this step, substantial athletic rehabilitation was started. The main training regime was leg extensions and leg curls, and

Table.10 The number of subjects in different WBIs conducted on subjects with grade II

WBI	Affected site	Non-affected site
0.80 or less	One subject	
0.80 ~ 0.85	Two subjects	
0.85 ~ 0.90	Two subjects	
0.90 ~ 0.95	One subject	One subject
0.95 ~ 0.10		Two subjects
0.10 or more		Three subjects

Table.11 The distance that the subjects could run for the first jogging

The distance without fatigue at the first jogging (m)	Number of subjects	Initial severity
50m ~ 100m	6	Five subjects with grade III, One with grade II
100m ~ 150m	2	One with grade III One with grade II
150m ~ 200m	2	All subjects were grade II.
200m or more	2	All subjects were grade II.

aimed at the enhancement of muscle strength as the load was increased gradually. Moreover, for overall training, exercises using barbells and dumbbells were conducted. In jogging, the distance was increased and they conducted dash and full-power running within a range that didn't cause anxiety. Moreover, they conducted trainings simulating Judo movements.

The WBIs measured at the mid-point of this step are shown in Table.12. In this table, the six subjects who reached the fourth step after surgery were included.

From these results, it was found that muscle strength was increasing smoothly, although there was considerable dispersion. As its causes, besides differences in the desire to wrestle with the rehabilitation, there was the difference of injured legs regarding a dominant leg or a non-dominant leg. When a dominant leg was injured, although the numerical value of the WBI at the affected side became larger than those of other subjects, the WBI at the non-affected side tended to be smaller. Those subjects whose recovery was delayed were likely comparable to other subjects. Thus, their mental support was conducted actively and they were instructed to

wrestle with the conditions patiently and confidently.

In medical rehabilitation, this is the stage which one has already completed the rehabilitation. Thus, because of the hard training, there was a concern that some subjects might drop out of the rehabilitation at this step. However, all subjects eventually achieved a WBI 1.0 and advanced to the fifth step.

The final goal in this step is to achieve a WBI 1.0. The subjects spent a lot of time increasing the WBI from 0.8 in the previous step to 1.0. Despite the time spent training, when the value became lower than previous values, the subjects were greatly discouraged. Thus, they were instructed to recognize the significance of the athletic training again and to give their best efforts in preventing its sequela and recurrence, and also to wrestle with the trainings diligently.

5) The fifth step

In this step, the training regime aiming at the return to athletic competition was planned and executed.

Making the WBI 1.2 its goal and increasing the load, the training for muscle strength,

Table.12 The number of subjects in different WBIs conducted on subject at the mid-point of fourth step

WBI	Affected site	Initial severity	Non-affected site	
0.85 or less	One subject	Grade III		
0.85 ~ 0.90	Three subjects	All subjects were grade III.		
0.90 ~ 0.95	Five subjects	Two with grade III Three with grade II		
0.95 ~ 1.00	Three subjects	All subjects were grade II.		
1.00 ~ 1.05			Six subjects	Four with grade III Two with grade II
1.05 ~ 1.10			Two subjects	All subjects were grade III.
1.10 ~ 1.15			Three subjects	All subjects were grade II.
1.15 or more			One subject	All subjects were grade II.

mainly with leg extensions and leg curls, was continuously conducted. Although full-power running was utilized several times in the previous step, the running was repeated in this step.

What gained the most attention was the training simulating the actual actions of Judo. This was because, even those subjects who conducted the athletic rehabilitation smoothly and sustained sufficient recovery of their physical strength, were bewildered by the training which simulated these actual actions.

There were many subjects who couldn't overcome the gap between the rehabilitation and the actual physical actions. After achieving a WBI 1.1 on the affected side, their later WBIs still remained at 1.1, which resulted in some of the subjects not being able to concentrate on the trainings. In the athletic trainings, the importance of mental support as well as physical support was recognized again. All 12 subjects in whom the athletic rehabilitation was attempted achieved the WBI 1.2 on the affected side and could return to competition. The mental effects of "We can do Judo as aggressively and as often as we choose because there is no anxiety and no fear for its sequela or recurrence" and "Even if it should recur by some chance, recovery is possible through athletic rehabilitation" could never

be obtained by medical rehabilitation.

2. Evaluation of muscle strength

Figs. 2 and 3 show the variation of the WBI values seen from the number of days after injury in the subjects with grade II and III, respectively. Because the project was completed at the step when the goal of a WBI 1.2 was achieved, the completion dates were individually different. Because the subjects with grade III underwent surgery, data for 150 days or more after the injury was used.

In the subjects with grade II, the number of

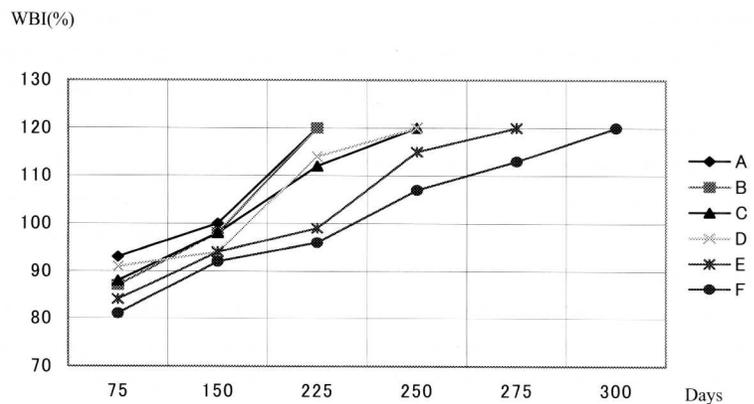


Fig.2 The variation of the WBI in the group with grade II

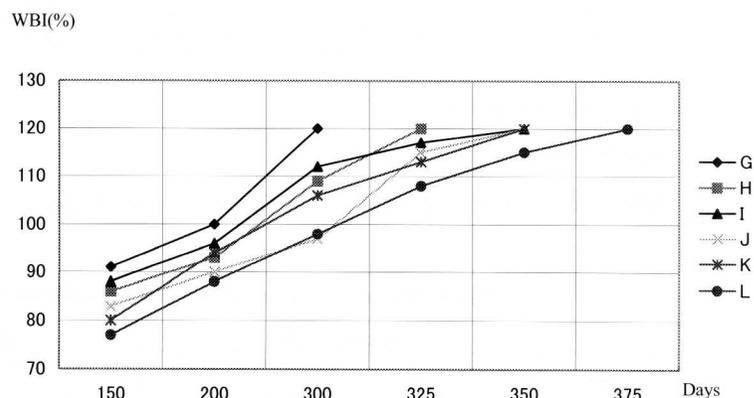


Fig.3 The variation of the WBI in the group with grade III

days necessary for their return was 225 days for two subjects, 250 for two, 275 for one, and 300 for one. On the other hand, in the subjects with grade III, the number of days was 300 for one, 325 for one, 350 for three, and 375 for one.

1) The number of days necessary to reach the target value

The number of days to reach the specific WBI value or better and differences according to severity were investigated. Table.13 shows the mean level of the number of days needed and the standard deviation. For the statistic evaluation, the non-paired t test was used and a level of $p < 0.05$ was made the significant difference.

In all cases of a WBI 0.8 or more to 1.2 or more, the subjects with grade II reached the goal in a significantly shorter time. With more severe conditions, it took longer to recover muscle strength.

2) The difference in the variation of the WBI

Next, the variation levels of the WBI were investigated for whether or not there were differences between the first half (50-150 days in

subjects with grade II and 150~200 days in subjects with grade III) and the latter half (150-300 days in subjects with grade II and 200-375 days in subjects with grade III), as well as for individual differences. For instance, as for the variation level of the WBI during the period from 50 to 70 days, the WBI value at 50 days was subtracted from the WBI value at 70 days and the variation level for the first half was calculated individually and the resultant level was made the individual variation level for the first half. Table.14 shows each mean level and standard deviation.

The paired t-test was conducted for mean variation levels for the first and latter halves with different severities. The results showed that the variation levels for the latter half were significantly higher than those for the first half in only the group with grade II severity (grade II, $t(5)=4.24$, $p < 0.01$; grade III, $t(5)=0.33$, ns). That is, in only the group with grade II, the improvements made during the first half of the project were greater than those during the latter half. In the group with grade III, despite the progress of the project, the degree of improvement was constant.

Table.13 The mean number of days needed for different WBI values

	WBI 0.8 or more	WBI 0.9 or more	WBI 1.0 or more	WBI 1.2 or more
Grade II	54.2 (9.32)	100.0 (32.27)	200.0 (38.19)	254.2 (26.68)
Grade III	154.17 (9.32)	191.7 (23.57)	262.5 (47.32)	341.7 (23.57)
t-value	16.9**	5.13*	2.30*	5.50**

Note 1: All n values are 5.

Note 2: * < 0.05 , ** < 0.01

Note 3: The inside of the parentheses indicates the standard deviation.

Table.14 The variation levels of the WBI with different severities

	The first half		The latter half	
	Mean level	Standard deviation	Mean level	Standard deviation
Grade II	0.028	0.0089	0.060	0.0091
Grade III	0.049	0.0130	0.047	0.0044

The degree of improvement influences the subject's motivation to diligently continue the athletic rehabilitation. Thus, mental support in compliance with the original injury condition is necessary. That is, for subjects with grade II, motivation during the first half is considered most important.

On the other hand, in the group with grade III, in the final stage with the WBI from 0.9-1.0 to 1.2, the improvement of the WBI varied among individual subjects. This finding indicates how difficult the WBI is increased from 0.9 to 1.2, namely the difficulty of the athletic rehabilitation partially. This also corresponds to the fact that some subjects demonstrated lowered desire during the fifth step. Thus, for subjects with grade III, their mental support is particularly important during the latter half.

Next, to investigate individual differences, a test for the significance of the dispersion regarding different numbers of days was conducted. However, because the number of days needed to attain the standard WBI varied, in regard to the latter half, the number of days whose data all subjects had reached was made the base for the test. The standard deviation among the subjects with grade II was 0.0089 for the first half and 0.0262 for the latter half. The standard deviation among the subjects with grade III was 0.0130 for the first half and 0.0116 for the latter half. The test for the significant difference of the dispersion revealed that the dispersion in the later half in only the subjects

with grade II was significantly greater (Grade II, $F(5.5)=8.76$, $p<0.05$); grade III, $F(5.5)=0.80$, n.s.). That is, when the severity was higher, no individual differences were present, similar to the results from the first half and the improvement rate is thus said to be similar to those of other people. On the other hand, in cases of milder injuries, the individual difference is assumed to be notable from about 150 days after the injury. In some subjects, their numerical value did not increase and their desire decreased midway through. Thus, it is considered important for the mental support by clinical psychological specialists to focus on continuing the training with the emphasis on personal goals rather than comparing with other people, especially in the latter half.

3. Functional evaluation

1) ROM value

The ROM test on the affected side was done using A for 130 degrees or more, B for 120-130 degrees, and C for 120 degrees or less. The results of the subjects with grade II showed that the AROM and PROM values reached A in three subjects at 40 days and the remaining three subjects at 50 days. All subjects with grade III reached A at 150 days. With a higher severity, the value was lower, and it was assumed that the severity of the original injury reflected more greatly on these results than the progress of the rehabilitation.

Next, the AROM values from the initial step

Table.15 Improvement results of AROM values (20 days to 40 days)

	Improvement		Subtotal	No change	
	B-A	C-B		C-C	
Grade II	3	3	6↑	0↓	
Grade III	0	2	2↓	4↑	

Note: At a 5% level, [↑] indicates that the frequency of the grade is significantly more and [↓] indicates that the frequency of the grade is significantly less.

when the dispersion of the severity was seen are taken up here. Table.15 shows how the AROM value improved during the period from day 20 to day 40. There was not one subject whom the AROM value became lower than the previous level. The results of a χ^2 test showed a significant difference between the grades ($\chi^2(1)=6.00, p<0.05$). Thus, the residual analysis was conducted with a 5% level and the results are shown by the arrows in Table.15. [\uparrow] indicates that the frequency of the grade is significantly more and [\downarrow] indicates that the frequency of the grade is significantly less. That is, the frequency of the subjects with grade II was higher than that of the subjects with grade III. The

difference in the severity can be said to be demonstrated in the results of the initial trainings.

2) Manual muscle test

The measured values of the manual muscle test were regarded as superior for 4 or more, good for 3, fair for 2, and poor for 1. The results of individual subjects are shown in Table.16 for knee extensions and in Table.17 for knee flexions. Taking these results and the results of ROM values into consideration, it can be said that function is recovering smoothly.

4. Femoral circumference

Usually, the difference in the femoral

Table.16 Manual muscle test of the femoral quadriceps muscle (knee extension)

	20 days	40 days	50 days	150 days
A	3	5		
B	4	5		
C	3	4	5	
D	3	5		
E	3	5		
F	2	4	5	
G	2	4		5
H	2	3		5
I	2	4		5
J	2	3		5
K	2	3		5
L	2	3		5

Table.17 Hamstring manual muscle test (knee flexion)

	20 days	40 days	50 days	150 days
A	4	5		
B	4	5		
C	3	5	5	
D	3	5		
E	3	5		
F	2	4	5	
G	2	3		5
H	2	3		5
I	2	4		5
J	2	3		5
K	2	3		5
L	2	3		5

circumference between the affected side and non-affected side is found at around ten days after an injury. Thus, the femoral circumference value at 10cm above the knee on the non-affected side, which was measured immediately after an injury, was made 100 and the difference in the number of days when the affected femoral site exceeded 100 was investigated among different severities. In the group with grade II, the mean days for exceeding 100 was 212.5 days with a standard deviation of 19.09. In the group with grade III, the mean number of days was 300.0 with a standard deviation of 32.27. The statistic investigation using the non-paired t-test revealed that the time required to reach a circumference of 100 in the group with grade II was significantly shorter than that in the group with grade III ($t(5)=5.22, p<0.01$). It was assumed that compared to the group with grade II, the group with grade III was confined to a bed for a longer time, which might have caused a greater reduction in the muscles. However, because muscle strength training was conducted while confined to a bed, the reduction of muscle strength in the group with grade III was less than expected. That is, it is essential to conduct training to preserve muscular mass from the initial step.

5. Health management conducted mainly by dieticians

No great change in body weight was observed in any of the subjects, however, the

body fat level changed during the course of the athletic rehabilitation. Table.18 shows the variation at each step. The χ^2 test showed a significant difference in the frequency among both grades ($\chi^2(6)=47.64, p<0.01$). Thus, the residual analysis was conducted at a 5% level and the results are indicated by arrows in Table.18. [\uparrow] indicates that the frequency of the grade is significantly more and [\downarrow] indicates that the frequency of the grade is significantly less. Although the body fat level increased in the first and second steps, it decreased in the third and fourth steps, and didn't change in the final fourth and fifth steps. That is, although the body fat in the initial stage after an injury increases because the training amount decreases, the level decreases gradually and smoothly through executing the training regime and the advice given by the dieticians. In the final step of the athletic rehabilitation, it is expected that the body will return to ideal form towards the return to actual competition.

6. Mental support offered mainly by clinical psychologists

1) Immediately after an injury

In interviews conducted immediately after their injury by clinical psychologists, all subjects had the same anxiety, "I may not be able to continue Judo anylonger" and the regretful feeling of, "Why have I had such an injury?" To alleviate such anxieties and regretful feelings, clinical psychologists repeatedly asked the

Table.18 The number of people experiencing changes in body fat level during the rehabilitation

	The 1st – 2nd	The 2nd – 3rd	The 3rd – 4th	The 4th – 5th
Increase	11 \uparrow	2	0 \downarrow	0 \downarrow
No change	1 \downarrow	7	4	11 \uparrow
Decrease	0 \downarrow	3	8 \uparrow	1

Note: At a 5% level, [\uparrow] indicates that the frequency of the grade is significantly more and [\downarrow] indicates that the frequency of the grade is significantly less.

subjects to explain in detail the situation in which they were injured. While the subjects didn't want to recall the situation, they also had a desire to be listened to regarding the situation by someone. Thus, the specialists asked them about the situation to allow them to arrange their feelings and to recognize their current situation. Then, the subjects wrestled with the athletic rehabilitation. However, during the rehabilitation, their anxiety and regretful feelings were not completely dissolved and they occasionally complained about their concerns regarding the rehabilitation. Especially, when they didn't reach a goal value and couldn't conduct the trainings in the manner in which they wanted, such concerns increased. They tended to compare their own progress in the rehabilitation with others', and when they found that they weren't progressing as well as others, their disappointment was high. In such situations, the clinical psychological specialists gave them hope and instructed them to wrestle with the athletic rehabilitation patiently and diligently.

2) Stage to return to competition

In the final stage, although many subjects showed positive attitudes, they also sometimes showed bewilderment. In most cases, the cause was that they felt the gap between the trainings and actual Judo actions. As the worst case, some subjects lost the desire to return, saying "I don't want to continue Judo anymore". For such cases,

the subjects were persuaded, being told, "This bewilderment is experienced by everybody when they return to competition and can be overcome only by accumulating the experience of competitions", and thereafter received trainings simulating actual Judo actions. At this stage, the fear of a recurrence of the injury occurs. For countermeasures to overcome this fear, the situation in which they were injured was reproduced repeatedly as was done in the initial step and the effects of the athletic rehabilitation were recognized and the training of simulated Judo actions was repeated.

7. Comparison between the athletic rehabilitation and other methods

The results of the athletic rehabilitation were compared with the results of a survey about actual situations carried out previously¹²⁾. The evaluation of muscle strength is summarized in Table.16. The results from the χ^2 test revealed significant differences in the frequency of grades in both groups with grade II and grade III (Grade II, $\chi^2(1)=18.30$, $p<0.01$; grade III, $\chi^2(1)=18.71$, $p<0.01$). Thus, a residual analysis was conducted with a 5% level and the results are shown by the arrows in Table.19. [\uparrow] indicates that the frequency of the grade is significantly more and [\downarrow] indicates that the frequency of the grade is significantly less. That is, the groups with the athletic rehabilitation showed significantly superior muscle strength than the group with the medical rehabilitation. It

Table.19 The number of people in different rehabilitations for the evaluation of muscle strength

	Grade II		Grade III	
	Excellent	Good/fair	Excellent	Good/fair
The athletic rehabilitation	6 \uparrow	0 \downarrow	6 \uparrow	0 \downarrow
The medical rehabilitation	11 \downarrow	47 \uparrow	4 \downarrow	26 \uparrow

Note: At a 5% level, [\uparrow] indicates that the frequency of the grade is significantly more and [\downarrow] indicates that the frequency of the grade is significantly less.

indicates that to recover muscle strength, the athletic rehabilitation is more effective than medical rehabilitation.

Table.20 shows the functional evaluation. The results of the χ^2 test revealed significant differences in the frequency of the grade in both groups with grade II and grade III. (Grade II, $\chi^2(1)=21.62, p<0.01$); grade III, $\chi^2(1)=18.71, p<0.01$). Thus, the residual analysis was conducted at a 5% level and the results are shown by the arrows in Table.20. [↑] indicates that the frequency of the grade is significantly more and [↓] indicates that the frequency of the grade is significantly less. That is, the groups with the athletic rehabilitation showed a significantly superior functional evaluation than the group with the medical rehabilitation. It indicates that to recover the affected function, the athletic rehabilitation is more effective than medical rehabilitation.

At a 5% level, [↑] indicates that the frequency of the grade is significantly more and [↓] indicates that the frequency of the grade is significantly less.

8. Current situation

After the subjects returned to competition, instructions for the trainings and follow-up observations were continued to prevent any recurrence in the subjects. Consequently, no subjects have had a recurrence of their ligament injury to the knee joints. When the effects of the ligament injuries on their subsequent sports

activities were asked of the subjects, they answered as follows: (1) I have begun to take cautions during ordinary training. (2) I have begun stressing on movements imaged rather than forced. (3) The sensation during actual competition hasn't changed from that felt before the injury.

Moreover, as for ordinary training, they answered as follows: (1) I conduct the training more carefully than before. (2) I always include stretching. (3) When using machines, I confirm the effects of the training by numerical values.

Athletic rehabilitation is intended to strengthen the condition at the affected site to a level higher than that before the injury, and to eliminate any mental anxiety and prevent its sequela and recurrence. From the above answers, it can be said that these intentions have been achieved sufficiently. Especially, it is essential that the athletic rehabilitation be continued after the subject has left the staff, and it is important for the subject to continuously repeat the trainings after returning to their sport. The subjects who received the athletic rehabilitation in this study realized that when they neglected the trainings for just a while, muscle strength decreased. Thus, continuing the trainings became one of their achievements.

In this study, the athletic rehabilitation program was carried out in only 12 cases and the results were limited to Judoists's. Thus, as a future subject, it will be necessary to increase the number of the cases and make the

Table.20 The number of people in different rehabilitations for the functional evaluation

	Grade II		Grade III	
	Excellent	Good/fair	Excellent	Good/fair
The athletic rehabilitation	6↑	0↓	6↑	0↓
The medical rehabilitation	9↓	49↑	4↓	26↑

At a 5% level, [↑] indicates that the frequency of the grade is significantly more and [↓] indicates that the frequency of the grade is significantly less.

effectiveness of the athletic rehabilitation persuasive. Moreover, it will be necessary to conduct the athletic rehabilitation in athletes of other athletic competitions and compare for whether or not similar effect to that in Judoists can be obtained and consider the program contents according to the difference of athletic competition. Those studies will prove the effect of the athletic rehabilitation with a higher reliability and generality.

Conclusion

The purpose of this study was to verify the effectiveness of athletic rehabilitation with a weight bearing index of 1.2 as the minimum recovery goal. Namely, we conducted our new athletic rehabilitation program on 12 Judo athletes with knee ligament injuries and determined the degree of their recovery, and we also compares the results obtained in the present study with those from the preceding studies. As a result, the following points were clarified:

- 1) When the effect of the athletic rehabilitation program in relieving from knee ligament injury was analyzed by severities of injuries, it was found that muscle strength required a longer period of time for recovery as the injury was severer. As for differences in WBI recovery, there was a greater variation in improvement and greater interindividual differences in the group of severity grade II subjects in the second half of the project, compared with those observed in the first half. Functional recovery in the early stage of the project was better in the group of severity grade II subjects than in the group of severity grade III subjects.
- 2) The athletic rehabilitation program conducted in the present study provided significantly better outcomes of muscle strength and functional recovery, as compared with those seen in the preceding studies. Irrespective of severities of injuries, this program was also effective for the increase in femoral circumference on the affected side, the decrease in body fat rate, and resolution of concern about sequelae and recurrence, which is a serious problem interferes with return to competitions.

These results indicate that the athletic rehabilitation conducted in the present study is an excellent procedure that can support injured athletes not only in physical aspects, but also in mental aspects. In the future, it is extremely important that this program should be made more aware and wider utilization in Japan because proper consideration has not been given to athletes with knee injuries.

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