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Effect of a 12-week Shoulder Stability Rehabilitation Program on the Range of Motion and Muscle Strength of Baseball Players with Shoulder Instability

Jin-Ho Yoon[1], Jae-Keun Oh[2], Ki-Jae Song[3*]
[1]Professor, Department of Physical Education, Korea National Sport University
[2]Professor, Department of Health and Exercise Science, Korea National Sport University
[3]Part-time lecturer, Department of Physical Education, Korea National Sport University

12주의 어깨 안정성 회복 프로그램이 견관절 불안정성 야구선수의 관절가동범위, 근력에 미치는 영향

윤진호[1], 오재근[2], 송기재[3*]
[1]한국체육대학교 체육학과 교수, [2]한국체육대학교 운동건강관리학과 교수, [3]한국체육대학교 체육학과 시간강사

Abstract This study investigated the effect of a 12-week rehabilitation program on the range of motion (ROM) and muscle strength of high school baseball players with shoulder instability. We allocated 12 players with shoulder instability to the rehabilitation group and 13 players without shoulder instability to the normal exercise group. Covariate analysis (ANCOVA) was performed to assess the ROM of the internal (IR) and external (ER) rotational joints before and after participating in the 12 weeks of rehabilitation, and two-way ANOVA was performed to assess isokinetic muscle strength. The statistical significance level was set at p<.05. The IR ROM of the dominant (D) shoulder with instability and non-dominant (ND) shoulder was significantly increased before and after the rehabilitation program. The total ROM of the D shoulder with instability significantly increased after rehabilitation. IR isokinetic strength significantly improved at an angular velocity of 180°/s after rehabilitation. These results indicate that the rehabilitation program used in this study could be effective in improving ROM and muscle strength in patients with shoulder instability. However, due to the limited results, additional research on the premise of extending the rehabilitation period is necessary.

Key Words : Shoulder Instability, Rehabilitation Program, Range of Motion, Isokinetic Strength, Baseball Player

요 약 이 연구는 12주간 재활 운동프로그램이 어깨 불안정성을 가진 고등학교 야구선수들의 관절가동범위와 근력에 미치는 효과를 알아보기 위해 실시하였다. 어깨 불안정성이 있는 것으로 판명된 재활 운동군 12명과 정상 운동군 13명을 선정하였다. 12주간 재활운동 참가 전·후 내·외회전 관절가동범위는 공변량분석(ANCOVA)을 실시하였으며, 등속성 근력은 이원변량분석(two-way ANOVA)을 실시하였으며, 통계적 유의수준은 p<.05로 설정 하였다. 관절가동범위는 불안정이 있는 우위측과 비-우위측 어깨의 경우 재활운동 전·후 내회전 ROM이 유의하게 증가했으며, Total ROM의 경우 불안정이 있는 우위측 어깨에서 재활운동 후 유의하게 증가했다. 등속성 근력의 경우 재활운동 후 내회전 근력이 각속도 180°/sec에서 유의하게 개선되었다. 본 연구 결과를 요약하면 12주간 재활운동 프로그램이 어깨 불안정성 환자의 ROM, 근력 개선에 효과적인 것으로 나타났다. 하지만 제한적 결과에 미루어 재활기간의 연장을 전제로 한 추가적 연구가 필요할 것으로 생각된다.

주제어 : 어깨불안정성, 재활운동프로그램, 관절가동범위, 등속성 근력, 야구선수

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*Corresponding Author : Ki-Jae Song(jordanforever@hanmail.net)

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1. Introduction

The shoulder or the glenohumeral (GH) joint is the joint with the widest range of motion (ROM) in the human body; approximately 7% of all sports injuries occur in this joint[1]. The shoulder consists of three bones (the clavicle, scapula, and humerus) together with the sternoclavicular (SC), acromioclavicular (AC), GH, and scapulothoracic (ST) joints and various muscles, including the rotator cuff, synarthrosis (ligament combinations), and other structures composed of dynamic connections it provides both stability and maximum mobility.

This anatomical structure enables the shoulder to perform various sports-related activities; however, the great mobility in itself can be a risk factor for injury[2]. Therefore, damage to the GH joint frequently occurs during exercise, with a high rate of recurrence being reported in young athletes[3]. Such repetitive injuries adversely affect the structures that provide stability to the GH joint, which leads to instability[4].

Chronic stress, especially experienced by overhead throwers practicing sports such as baseball, volleyball, and tennis, is a major factor in predicting anterior instability of the GH joint[5]. The incidence rate of injuries is high for athletes participating in events that require excessive external rotation with abduction and extension in the horizontal plane of the shoulder[6].

Recent studies have suggested that, when playing baseball, overload of the GH joint capsule in a position of excessive ROM causes a gradual weakening of the anterior/inferior static bonds and increases the risk of dislocating the GH joint[7]. Alterations in the ROM of the GH joint, such as an increase in the external (ER) ROM and a limitation of the internal (IR) ROM, are mainly observed in athletes who are required to perform frequent overhead throws. This altered mobility in the GH joint of an overhead thrower is more closely related to anatomical changes of the proximal humerus than to the changes in soft tissue structures surrounding the joint[8]. In baseball players, shoulder instability causes changes in the scapulohumeral joint axis and causes joint capsule, glenoid, rotator cuff tendon injury[9]. It also causes pain in the late part of the acceleration phase and a decrease in the pitching velocity[10].

Therefore, the reported changes in the ROM and muscle function of the shoulders of baseball players can be considered to result from the structural changes caused by adapting to the sport-specific physiological demands of frequently throwing a ball overhead.

Researchers are paying attention to whether this structural adaptation adversely affects the stability of the GH joint, or whether the change in stability is related to injury[11]. That is, the anatomical change of the GH joint due to chronic stress can be considered an adaptation due to exercise, although this may cause injury to the shoulder joint. Therefore, it is necessary to improve the stability of the structures of the shoulder joint according to the altered anatomical structure. In addition, the purpose of rehabilitation for instability of the GH joint should focus on preventing shoulder injury and recurrence by strengthening dynamic muscle function of the soft tissue that contributes to stabilization of the joint[1].

Various studies have been conducted on shoulder instability, and various improvement measures have been proposed. However, most studies have confirmed shoulder instability by physical and radiographic examination and have suggested surgical treatment. Reports on the practical effects of exercise rehabilitation are insufficient. The purpose of this study was to assess the changes in stability, strength, and ROM of the GH joint after 12 weeks of rehabilitation training in high school baseball players with shoulder instability.

2. Methods

2.1 Participants

We recruited 25 high school baseball players who visited the R Rehabilitation Center in Seoul. Both the subjects and their parents were informed of the exercise program and provided written informed consent for participation in the study and publication of their data. Twelve patients who were classified as having shoulder instability according to expert surgeons were assigned to the rehabilitation exercise group (P: Patient), while 13 patients without shoulder instability were assigned to the normal exercise group (H: Healthy). The shoulder on the dominant side of the body was selected as the dominant shoulder (D) and the other shoulder as the non-dominant shoulder (ND). The Physical characteristics of the participants are listed in Table 1.

Table 1. Physical characteristics of participants

Group	Age(yrs)	Height (cm)	Weight (kg)	BMI (kg/m2)	PF (%)
Patient group (N=12)	17.82 ±1.40	178.45 ±4.03	84.76 ±9.34	26.64 ±3.03	20.86 ±5.97
Healthy group (N=13)	17.57 ±1.87	179.93 ±7.10	82.21 ±8.41	25.39 ±2.17	17.83 ±3.27
Sig	.723	.554	.744	.377	.285

BMI: Body Mass Index, PF: Percent body Fat

2.2 Measurement

2.2.1 Shoulder ROM

To measure the IR and ER ROM of the shoulder joint, the participant was positioned supine on a mobile bed. The arm to be measured was abducted by 90° with the relevant elbow flexed by 90°, and a goniometer (Jamar, USA) was used to record the IR, ER, total ROM, and changes in the IR/total ROM and ER/total ROM[12].

2.2.2 Muscle strength

An isokinetic muscle strength measuring device (CSMi, Humax Co., USA) was used to measure the IR and ER strength of the shoulder joint while the participant was in the supine position. Three warm-up exercises at angular velocities of 60°/s, 180°/s, and 240°/s were performed five times each; measurements were subsequently recorded five, five, and 25 times, respectively. The IR and ER strength according to body weight and the ER/IR ratio were quantified[13].

2.3 Rehabilitation program

The process of shoulder rehabilitation was based on the four-stage program proposed by Wilk, Meister & Andrews, (2002)[14]; however, in the case of the acute phase, considering that hospital treatment and methods of stabilization are the main treatments, some of the processes of the 2nd (intermediate phase), 3rd (advanced strengthening phase), and 4th (return-to-activity) phase were reconstructed by an expert panel. The program was structured as follows: 10 minutes of stretching, 90 minutes of main exercises, and 10 minutes of cool-down. Three sets of each exercise were performed, 10-15 repetitions per set; however, from the 3rd stage onwards, the structure was changed according to baseball-specific characteristics and the purpose of the exercise. The purpose and details of the rehabilitation program are listed in Table 2.

Table 2. Rehabilitation protocol

Stage		Exercises and modalities
Warm up		Stretching
Main exercise	Acute phase	Cryotherapy, ultrasound, electrical stimulation, Flexibility and stretching for posterior shoulder muscles, Rotator cuff strengthening, Scapular muscle strengthening, Dynamic stabilization exercises, Closed kinetic chain exercises, Proprioception training, Abstain from throwing
	Intermediate phase	Continue stretching and flexibility, Progress isotonic strengthening, Complete shoulder program, Thrower's Ten program, Rhythmic stabilization drills, Initiate core strengthening program, Initiate leg program
	Advanced strengthening phase	Flexibility and stretching, Rhythmic stabilization drills, Thrower's Ten program, Initiate plyometric program, Initiate endurance drills, Initiate short-distance throwing program
	Return to activity phase	Stretching and flexibility drills, Thrower's Ten program, Plyometric program, Progress interval throwing program to competitive Throwing
Cool down		Shoulder stretching

2.4 Statistical analysis

Data were analyzed using Windows SPSS version 19.0 (IBM Corp., Armonk, NY, USA). A two-way analysis of variance (ANOVA) was conducted to verify the difference in isokinetic strength according to the measurement period (before and after rehabilitation) between the groups. A covariate analysis (ANCOVA) was performed for ROM measurements that were significantly different between groups, considering that this study was conducted on players with shoulder instability. For post-hoc analysis, an independent t-test was performed. The statistical significance level was set at $p<.05$.

3. Result

3.1 Changes in IR ROM

As shown in Table 3, in the assessment of the effect of exercise on shoulder instability and with the IR ROM score prior to intervention included as a covariate, no significant difference between the pre- and post-rehabilitation groups was found ($p=.118$). However, IR ROM before rehabilitation significantly affected the outcome after rehabilitation ($p<.001$) and, as a result of the post-hoc analysis, the IR ROM of the PD group significantly increased by 18.1% (post-rehabilitation: 54.83±10.73; pre-rehabilitation: 44.92±8.93; $p<.001$), while the IR ROM of the PND group significantly increased by 9.7% (post-rehabilitation: 61.25±6.93; pre-rehabilitation: 55.29±7.93; $p=.001$).

3.2 Changes in ER ROM

We included the pre-rehabilitation ER ROM as a covariate. As shown in Table 3, no significant difference was found between the pre- and post-rehabilitation groups regarding ER ROM ($p=.720$). However, ER ROM before rehabilitation had a significant effect on the outcome after rehabilitation ($p=.006$), although the post-hoc analysis continued to reveal no significant difference between the groups pre- and post-rehabilitation.

3.3 Changes in total ROM

We included the pre-rehabilitation total ROM as a covariate; as shown in Table 3, there was no significant difference between the pre- and post-rehabilitation groups ($p=.661$). However, the total ROM before rehabilitation had a significant effect on the outcome after rehabilitation ($p<.001$) and the post-hoc analysis revealed a significant increase of 8.8% in the total ROM of the PD group (post-rehabilitation: 156.92±13.36; pre-rehabilitation: 143.13±13.52; $p<.001$).

3.4 Changes in the IR/total ROM ratio

We included the pre-rehabilitation IR/total ROM ratio as a covariate; as shown in Table 3, there was no significant difference between the pre- and post-rehabilitation groups (p=.446). However, the IR/total ROM ratio before rehabilitation had a significant effect on the outcome after rehabilitation (p<.001).

The post-hoc analysis revealed that the ratio of the PD group significantly increased by 9.6% (post-rehabilitation: 34.58±4.98; pre-rehabilitation: 31.25±5.29; p=.022), while that of the PND group significantly increased by 7.3% (post-rehabilitation: 37.75±3.79; pre-rehabilitation: 35.00±3.88; p=.018).

Table 3. Changes in shoulder range of motion between the groups

	Group	Pre-rehabilitation	Post-rehabilitation	*Significance*
IR ROM	PD	44.92 ± 8.93	54.83 ± 10.73***	Model : <.001
	PND	55.29 ± 7.93	61.25 ± 6.93**	Covariate : <.001
	HD	63.09 ± 7.87	64.38 ± 7.86	Group : .118
ER ROM	PD	98.21 ± 11.13	102.08 ± 7.49	Model : .042
	PND	103.25 ± 10.63	101.92 ± 14.13	Covariate : .006
	HD	102.38 ± 6.39	104.00 ± 4.06	Group : .720
Total ROM	PD	143.13 ± 13.52	156.92 ± 13.36***	Model : <.001
	PND	158.54 ± 13.84	163.17 ± 17.12	Covariate : <.001
	HD	165.48 ± 11.69	168.38 ± 8.08$	Group : .661
IR / total ROM ratio (%)	PD	31.25 ± 5.29	34.58 ± 4.98*	Mode l: <.001
	PND	35.00 ± 3.88	37.75 ± 3.79*	Covariate : <.001
	HD	38.08 ± 3.17	38.15 ± 3.56	Group : .446
ER / total ROM ratio (%)	PD	68.75 ± 5.29	65.42 ± 4.98*	Model : <.001
	PND	65.00 ± 3.88	62.33 ± 3.80*	Covariate : <.001
	HD	61.92 ± 3.17	61.85 ± 3.56	Group : .479

IR, internal rotation; ROM, range of motion; ER, external rotation; PD, patient dominant; PND, patient non-dominant; HD, healthy dominant

3.5 Change of ER/total ROM ratio

We included the pre-rehabilitation ER/total ROM ratio as a covariate; as shown in Table 3, there was no significant difference between the pre- and post-rehabilitation groups (p=.479). However, the ER ratio before rehabilitation had a significant effect on the outcome after rehabilitation (p<.001). The post-hoc analysis revealed that the ratio of the PD group significantly decreased by 4.8% (post-rehabilitation: 65.42±4.98; pre-rehabilitation: 68.75±5.29; p=.022), while that of the PND group significantly decreased by 4.1% (post-rehabilitation: 62.33±3.80; pre-rehabilitation: 65.00±3.88; p=.021).

3.6 Changes in isokinetic strength

We also analyzed the changes in the isokinetic strength of the shoulder. As shown in Table 4, there was no significant difference in isokinetic strength between the pre- and post-rehabilitation groups or time periods for any of the groups. A significant difference between the periods was found for the IR strength (p=.049) and ER/IR strength ratio (p=.003) at an angular velocity of 180°/s. Additionally, there was a significant difference in ER/IR strength ratio (p=.017) at an angular velocity of 240°/s. In the post-hoc analysis, IR strength (180°/s) increased by 16.95% (post-rehabilitation: 44.10±7.61; pre-rehabilitation: 36.63±8.19) in the PD group, while the ER/IR strength ratio (180°/s) in the PD group decreased by 16.44% (post-rehabilitation: 84.50±6.60; pre-rehabilitation: 101.13±12.64).

Table 4. Changes in shoulder strength between the groups

	Group	Pre-rehabilitation	Post-rehabilitation	*Significance*
IR 60°/s	PD	38.63 ± 9.16	44.30 ± 6.48	Group: .956
	PND	41.22 ± 6.16	40.86 ± 7.63	Time: .382
	HD	41.80 ± 3.11	41.78 ± 5.59	Group × Time: .360
IR 180°/s	PD	36.63 ± 8.19	44.10 ± 7.61*	Group: .565
	PND	40.56 ± 6.88	41.00 ± 8.58	Time: .049
	HD	34.80 ± 5.89	40.89 ± 8.54	Group × Time: .404
IR 240°/s	PD	38.88 ± 8.18	43.50 ± 8.18	Group: .729
	PND	40.44 ± 6.21	41.43 ± 7.50	Time: .132
	HD	36.80 ± 3.03	41.44 ± 8.72	Group × Time: .737
ER 60°/s	PD	34.88 ± 6.51	37.30 ± 7.47	Group: .898
	PND	38.00 ± 4.66	36.00 ± 7.07	Time: .957
	HD	36.60 ± 1.52	35.89 ± 5.04	Group × Time: .546
ER 180°/s	PD	36.50 ± 6.93	37.50 ± 6.85	Group: .212
	PND	38.00 ± 5.74	36.71 ± 7.78	Time: .867
	HD	32.60 ± 5.13	33.89 ± 6.99	Group × Time: .844
ER 240°/s	PD	35.25 ± 6.98	37.70 ± 7.94	Group: .371
	PND	39.89 ± 6.62	37.86 ± 9.48	Time: .973
	HD	35.20 ± 4.15	35.00 ± 6.38	Group × Time: .668
ER / IR 60°/s	PD	92.75 ± 14.77	83.20 ± 6.81	Group: .536
	PND	93.11 ± 11.10	89.29 ± 12.31	Time: .111
	HD	88.00 ± 6.71	86.22 ± 8.64	Group × Time: .562
ER / IR 180°/s	PD	101.13 ± 12.64	84.50 ± 6.60**	Group: .679
	PND	94.44 ± 9.15	90.71 ± 13.00	Time: .003
	HD	95.00 ± 10.98	83.89 ± 14.38	Group × Time: .265
ER / IR 240°/s	PD	92.13 ± 10.36	86.10 ± 5.72	Group: .220
	PND	99.11 ± 9.16	91.57 ± 14.26	Time: .017
	HD	95.60 ± 3.78	86.33 ± 13.62	Group × Time: .912

IR, internal rotation; ER, external rotation; PD, patient dominant; PND, patient non-dominant; HD, healthy dominant

4. Discussion

In baseball, throwing is one of the most frequently executed movements. Pitchers are required to perform excessive ER without difficulty; therefore, it is necessary to ensure sufficient ROM of the shoulder but, at the same time, stability is essential to prevent injuries caused by instability of the humeral head. This delicate balance between shoulder mobility and stability is termedthe thrower's paradox[14]. The repetitive throwing action results in specific adaptations in shoulder ROM[15].

In athletes who frequently perform overhead throwing motions, increased laxity of the shoulder joint capsule, excessive ROM, and limited flexibility can lead to subacromial impingement syndrome and instability of the GH joint[16,17]. In particular, the limitation of shoulder ROM, which is a major concern in relation to treatment, is known to be caused by issues such as structural deformation and pain of the joint tissue due to inflammatory reactions or immobilization[18]. Therefore, one of the primary goals of the rehabilitation program is to improve the athlete's shoulder stabilization and to control the anterior movement of the humeral head, while the other essential goal is to restore the flexibility of the shoulder joint's posterior rotator cuff muscles[14]. ROM exercises provide nutrients to the joint cartilage, helps in the alignment and resynthesis of collagen tissues[19], and is known to be effective in preventing scar tissue formation and tissue stenosis[20].

Many researchers reported that pitching

caused an increase in ER ROM and a decrease in IR ROM, and most previous studies have reported similar results[14, 21]. In this regard, Crockett et al[22] reported that as age increases in baseball players who frequently perform throwing motions, there is a difference in the ROM of the dominant and non-dominant shoulder and that the structure of the soft tissue and bones changes due to the repetitive motions. Therefore, IR ROM of the dominant shoulder decreased and ER ROM increased, but there were no changes in the total ROM.

Scher et al[23] showed that instability limits shoulder ROM and indicated that the total ROM of a healthy shoulder and a non-dominant shoulder without instability was significantly greater than that of an unstable dominant shoulder. In this study, a significant increase was found in the total ROM of the shoulder with instability before and after rehabilitation. These results can be considered to satisfy the proposal of Wilk et al[14] in that the rehabilitation program conducted in this study should also be aimed at the recovery of ROM. However, after rehabilitation, the shoulder with instability continued to show a smaller total ROM than the shoulder without instability, which is considered to be due to an insufficient rehabilitation period. Therefore, a longer participation period should be considered for complete recovery.

The IR ROM, as well as total ROM, of the non-dominant shoulder without instability was significantly larger than that of the dominant shoulder with instability. Additionally, a significant improvement in IR ROM of the dominant shoulder was observed after participation in the rehabilitation program. This is considered to be due to the change in IR ROM when considering the ER ROM, where no significant difference was observed in either of the groups or periods. In addition, Kuhn et al[24] reported that the cause of the decreased IR ROM was a contraction of the thrower's posterior joint capsule. In order to decrease the risk of shoulder and elbow injuries, baseball players have to restore IR ROM due to posterior capsule tightness[25]. Therefore, regarding ROM and the rehabilitation program used in this study, it is considered that the program was designed to reduce the contraction of the posterior shoulder and subscapular soft tissue.

Isokinetic exercise allows for maximum muscle contraction at a limited ROM and is widely used in functional recovery training, sports medicine, and other sports-related fields. In particular, isokinetic exercise equipment is widely used to evaluate the degree of rehabilitation after an injury as a useful tool for improving muscle strength[26]. In athletes who mainly use a single upper limb, the shoulder joint's IR and ER force tests are important for injury prevention and rehabilitation exercise, and muscle strength evaluation must be performed with initial ROM recovery[14,27].

Brown et al[28] found that, when measured with the shoulder joint abducted to 90°, the pro baseball pitcher's dominant shoulder's IR and ER power were higher than that of the non-dominant side, reporting an IR/ER ratio of 3:2. Wilk et al[29] reported that the ratio was 65% at 180°/s and 61% at 300°/s. For proper muscle balance of the shoulder joint, the strength of the muscles responsible for ER should be at least 65% of that of the muscles responsible for IR, and the most appropriate ratio for the ER/IR rotator muscles is 66-75%, which should be maintained[30]. Therefore, at initial rehabilitation, the stability of the shoulder joint should be secured through reinforcement of the muscles responsible for IR are relatively stable compared to those responsible for ER, and comprehensive improvement of the entire muscle group should subsequently be performed.

In the present study, the IR strength of the unstable shoulder before and after rehabilitation was significantly increased at an angular velocity of 180°/s compared to the shoulder without instability. In addition, the ratio of the ER/IR strength also significantly decreased at angular velocities of 180°/s and 240°/s. As suggested by Myers et al[31] it is possible that the rehabilitation program used in this study had a beneficial effect on IR and ER muscle strength by reducing the risk of fatigue and injury of the shoulder muscles by balancing the IR and ER forces of the shoulder joint. However, the ER/IR strength ratio was found to be lower than the general recommended ratio of 66-75%. Since the IR and ER strength was required to be improved at the same time, but the recovery of the weakened IR strength after injury was considered more important, it is believed that the rehabilitation program in this study focused on the recovery of the IR strength. Therefore, due to the practical limitations of this program, a period of 12 weeks of rehabilitation exercise alone does not seem to be sufficient to restore the pre-injury functional level, and long-term, systematic management is deemed necessary to extend the life of the athlete and restore optimal performance.

5. Conclusion

We investigated the effect of a 12-week rehabilitation program on the stability and muscle strength of baseball players with shoulder instability. The unstable shoulder showed an increase in total ROM after exercise rehabilitation; this was found to be the main cause of the increase in IR ROM. However, even after an increase in the IR ROM, it was found to be inferior to that of the shoulder without instability; therefore, a longer period of rehabilitation should be considered. IR strength significantly improved after exercise rehabilitation at an angular velocity of 180°/s, and beneficial changes were observed in the case of healthy shoulders. However, if the ER/IR muscle ratio is high, long-term training as described above should be continued. In view of the above results, the rehabilitation program used in this study could be effective for improving ROM and isokinetic muscle strength in patients with shoulder instability.

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윤 진 호(Jin-Ho Yoon) [정회원]

· 2006년 2월 : 한국체육대학교 대학원 체육학과(체육학석사)
· 2010년 8월 : 한국체육대학교 대학원 체육학과(이학박사)
· 2021년 9월 ~ 현재 : 한국체육대학교 체육학과 교수

· 관심분야 : 스포츠의학, 운동손상, 운동재활. 선수트레이닝
· E-Mail : tkd97@hanmail.net

오 재 근(Jae-Keun Oh) [정회원]

· 1994년 8월 : 고려대학교 대학원 체육학과(이학박사)
· 1999년 2월 : 경희대학교 한의과 대학원 한의학과(한의학박사)
· 1996년 3월 ~ 현재 : 한국체육대학교 운동건강관리학과 교수

· 관심분야 : 스포츠의학, 스포츠한의학. 운동손상, 운동재활
· E-Mail : ojk8688@hanmail.net

송 기 재(Ki-Jae Song) [정회원]

· 2005년 2월 : 명지대학교 사회체육학과(체육학학사)
· 2011년 2월 : 한국체육대학교 체육학과(체육학석사)
· 2015년 2월 : 한국체육대학교 체육학과(이학박사)

· 2014년 3월 ~ 현재 : 한국체육대학교 체육학과 시간강사
· 관심분야 : 스포츠의학, 운동재활, 선수트레이닝, 운동상해
· E-Mail : jordanforever@hanmail.net