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Original Article

Effects of lower extremity injuries on aerobic exercise capacity, anaerobic power, and knee isokinetic muscular function in high school soccer players

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Abstract. [Purpose] The study investigated the effects of lower extremity injuries on aerobic exercise capacity, anaerobic power, and knee isokinetic muscular function in high school soccer players. [Subjects and Methods] The study assessed U High School soccer players (n=40) in S area, South Korea, divided into 2 groups: a lower extremity injury group (n=16) comprising those with knee and ankle injuries and a control group (n=24) without injury. Aerobic exercise capacity, anaerobic power, and knee isokinetic muscular function were compared and analyzed. [Results] Regarding the aerobic exercise capacity test, significant differences were observed in maximal oxygen uptake and anaerobic threshold between both groups. For the anaerobic power test, no significant difference was observed in peak power and average power between the groups; however, a significant difference in fatigue index was noted. Regarding the knee isokinetic muscular test, no significant difference was noted in knee flexion, extension, and flexion/extension ratio between both groups. [Conclusion] Lower extremity injury was associated with reduced aerobic exercise capacity and a higher fatigue index with respect to anaerobic exercise capacity. Therefore, it seems necessary to establish post-injury training programs that improve aerobic and anaerobic exercise capacity for soccer players who experience lower extremity injury.

Keywords: Lower extremity injuries, Aerobic exercise capacity, Anaerobic power

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INTRODUCTION

Success or failure in a soccer game is determined by various factors including physical, psychological, technical, and tactical factors. In terms of physical fitness, a soccer player runs 10–11 km on average and a maximum of 13.5 km during a 90-minute soccer match, although the distance covered by players varies depending on the playing position[1, 2)]. Therefore, it is important for soccer players to increase cardiorespiratory endurance. Aerobic exercise capacity, which enables them to continue play for a long time. In addition, because soccer players must frequently perform technical movements such as kicking, passing, dribbling tackling, heading, jumping, and turning, anaerobic power, and muscular function are substantially required[3, 4)]. In particular, with increased physical fitness, the risk of exercise-related injury decreases and there is a high probability of successfully performing soccer skills and tactics[5)]. Consequently, aerobic and anaerobic exercise capacity and muscular function are essential factors for performing individual skills and adhering to team tactics during matches.

Soccer, however, is often associated with musculoskeletal injuries due to contact with an opponent or non-contact at the

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time of turning and muscle stress during a match or exercise. In particular, since the quadriceps and hamstring are the main active muscles in soccer players, the rate of knee and ankle injuries in the lower extremities is high[6, 7]. The common types of soccer injuries in the lower extremities include knee and ankle sprainsor ruptures[8]. Such soccer injuries in the lower extremities have negative effects on aerobic exercise capacity, anaerobic power, and muscular function, which are essential for soccer games. Moreover, as team play is important in soccer, the physical fitness and sports injuries of team players deteriorate their training and soccer performance[9].

Although a number of studies on the physical characteristics of soccer players and their injuries have been conducted[10–13], there is a lack of basic data analyzing and comparing the effects of lower extremity injuries on aerobic exercise capacity, anaerobic power, and isokinetic muscular strength which are important for soccer performance.

Therefore, the present study aimed to investigate the effects of lower extremity injuries on aerobic exercise capacity, anaerobic power, and knee isokinetic muscular strength in high school soccer players and to provide data for designing training programs that are effective in improving athletic performance.

SUBJECTS AND METHODS

The subjects of the present study were 40 soccer players at U High School who visited and underwent medical examination at the National Fitness Center in Seoul, South Korea in December 2016. The subjects were divided into a lower extremity injury group (n=16) and a control group without injury (n=24). The subjects in the lower extremity injury group included those with medial and lateral collateral knee ligament injuries, patellar tendonitis, knee contusion, ankle sprain, or ankle contusion, who did not require surgical treatment but were restricted in soccer games or training within the past 1 year. In addition, the subjects in the lower extremity showed normal findings without any pain or functional limitation after receiving physical therapy and rehabilitation exercise program for more than 1 month, and thus, returned to training or competition.

The study was approved by the Ethics and Research Committee involving human beings of the institution. All the subjects gave their written informed consent before participating in the study.

Height and weight in the anthropometric test were measured in 0.1 cm increments using an automatic extensometer (Jenix DS-102, Korea). Body fat percentage was measured using a bioelectrical impedance analyzer (X-Scanplus II, Korea).

The aerobic exercise capacity test was performed using exercise stress test equipment (Quiton, USA) and an automatic breath gas analysis system (Jaeger, Germany). In the exercise stress test, the maximal oxygen uptake and anaerobic threshold were measured using the KISS protocol, which was set up to increase the speed of 20 m/min per 2 minutes starting at a speed of 80 m/min at a slope of 6%. The end of exercise test was performed according to the detailed guidelines of the ACSM[14].

Anaerobic power test was performed using an electromagnetic ergometer (Ergomedic894Ea, Germany). The measurement method was to adjust and set the saddle height so that the knee of each subject could have a flexion of about 5°, and thus, 0.075 kp per unit weight was supposed to be applied when reaching one’s maximum speed. Afterward, a tester in synchronization with the computer verbally counted a 5-second count down following warm-up and then verbally gave a “Start” signal, after which peak anaerobic power, average power, and fatigue index were measured while encouraging subjects to perform the exercise as much as possible for 30 seconds.

The knee isokinetic function test was performed using Biodex system-3 (Biodex Co., USA), an isokinetic dynamometer. The loading speed was set at an angular velocity of 60°/sec and three repeated measurements for the left and right knees were taken. Knee extensor and flexor muscle strength were measured after adjusting for gravity to limit the influence of gravity.

Data analysis was performed using SPSS statistical program (Version, 18.0). An independent t-test was performed to determine significant differences in aerobic exercise capacity, anaerobic power, and knee isokinetic muscular function. Statistical significance (α) was set at $p<0.05$.

RESULTS

There was no significant difference in the physical characteristics of the subjects between the lower extremity injury group and the control group (Table 1).

The results of the aerobic exercise capacity test showed that maximal oxygen uptake ($p<0.008$), anaerobic threshold ($p<0.000$), and anaerobic threshold time ($p<0.017$) were significantly lower in the injury group than in the control group. However, there was no significant difference in resting heart rate, maximal heart rate, and exercise duration (Table 2).

The results of the anaerobic power test showed no significant difference in peak power and average power between the lower extremity injury group and the control group. However, fatigue index was significantly higher in the injury group than in the control group ($p<0.008$) (Table 3).

The results of the knee isokinetic muscular function test showed no significant difference in knee extension, flexion, and extension/flexion ratio between the lower extremity injury group and the control group (Table 4).

DISCUSSION

The present study aimed to compare and analyze aerobic exercise capacity, anaerobic power, and knee isokinetic muscular

Table 1. Physical characteristics of subjects

Variables	Control group (n=24)	Lower extremity injury group (n=16)
Age (yrs)	15.7 ± 0.8	15.9 ± 0.8
Height (cm)	174.2 ± 6.0	175.7 ± 6.9
Weight (kg)	65.0 ± 6.2	66.6 ± 8.5
Body mass index (kg/cm^2)	21.2 ± 1.5	21.2 ± 2.0
Body fat (%)	15.5 ± 2.9	16.0 ± 3.8
Muscle mass (kg)	50.7 ± 4.6	51.7 ± 4.8

Values are shown as mean ± SD.

Table 2. Comparison of aerobic exercise capacity between the control group and lower extremity injury group

Variable	Control group (n=24)	Lower extremity injury group (n=16)
HR rest (beats/min)	77.8 ± 10.8	74.0 + 13.1
HR max (beats/min)	193.2 ± 8.3	193.9 ± 13.5
VO_2max (ml/kg/min)	62.7 ± 6.1	57.6 ± 5.2
AT (ml/kg/min)	43.9 ± 4.7	37.3 ± 5.3***
AT (%)	70.0 ± 6.5	64.6 ± 6.7*
Exercise time (sec)	956.4 ± 95.9	969.9 ± 92.6

Values are shown as mean ± SD.
HR: Heart rate; AT: Anaerobic threshold
*$p<0.05$, ***$p<0.001$

Table 3. Comparison of anaerobic power between the control group and lower extremity injury group

Variable	Control group (n=24)	Lower extremity injury group (n=16)
Peak power (watts)	954.5 ± 154.4	1024.6 ± 185.5
Peak power (watts/kg)	14.7 ± 1.7	15.6 ± 1.8
Average power (watts)	467.9 ± 61.0	430.3 ± 96.2
Average power (watts/kg)	7.2 ± 0.7	6.8 ± 0.7
Fatigue index (%)	52.2 ± 11.8	60.2 ± 11.8*

Values are shown as mean ± SD.
Fatigue index=(peak power−min power)/peak power ×100
*$p<0.05$

Table 4. Comparison of knee isokinetic strength between the control group and lower extremity injury group

Variable		Control group (n=24)	Lower extremity injury group (n=16)
Knee extension	Right %BW (Nm)	331.6 ± 43.2	329.1 ± 52.4
	Left %BW (Nm)	330.2 ± 32.7	315.5 ± 54.3
	deficit	−0.8 ± 14.4	3.9 ± 8.6
Knee flexion	Right %BW (Nm)	169.7 ± 25.5	161.9 ± 31.6
	Left %BW (Nm)	167.9 ± 26.0	151.2 ± 30.7
	deficit	0.0 ± 15.0	3.2 ± 14.5
Ratio	Right (%)	51.6 ± 8.2	49.6 ± 9.0
	Left (%)	51.0 ± 7.4	49.3 ± 7.6

Values are shown as mean ± SD.
BW: body weight

function between the lower extremity injury group and the control group among high school soccer players. The results of the present study revealed significant differences in aerobic exercise capacity regarding VO_2max, anaerobic threshold, and anaerobic power with respect to fatigue index between the lower extremity injury group and the control group. However, no significant difference was found in knee isokinetic muscular function between the lower extremity injury group and the control group.

Soccer is a high-intensity, intermittent, and non-continuous exercise, in which team play is important and where there may be rapid switching between offense and defense. In particular, as pivoting on the axis of rotation, turning in a slow-down situation, or landing movements after jumps are repeatedly required in soccer, there is a high risk of lower extremity injuries among soccer players[15]. However, soccer players generally return to play after the effectiveness of any post-injury rehabilitation program is evaluated[16, 17]. In particular, when returning to play, it is important for players to have sufficient aerobic exercise capacity for continuous movement during a 90-minute soccer game. In other words, the exercise intensity when running during a soccer match should reach about 80% of VO_2max, similar to the anaerobic threshold[1, 2]. In the present study, VO_2max and anaerobic threshold levels were found to be lower in the lower extremity injury group than in the control group. Some studies have suggested that decreased aerobic exercise capacity in athletes can lead to early fatigue and sports injuries[10, 18]. Therefore, it is thought that soccer players with injuries in the lower extremities need to be followed up with VO_2max assessment, and measures must be put in place to reduce the risk of re-injury and improve aerobic exercise capacity when designing physical fitness training programs after lower extremity injury.

In addition, soccer is a 90-minute game with first and second halves, but soccer players need anaerobic exercise capacity to perform instantaneously or repeated movements within a short time[19, 20]. The results of the present study showed no significant difference in peak power and average power regarding anaerobic power between the lower extremity injury group and the control group. However, fatigue index was found to be higher in the lower extremity injury group. The fatigue index is used to analyze the tendency to reduce from peak anaerobic power to minimum power. Therefore, reinforced training programs for soccer players are needed to increase fatigue resistance and maintain peak power after lower extremity injuries.

Soccer is associated with a high incidence of injuries in the lower extremities. Since joint instability, reduced muscle strength, and muscular unbalance between agonist and antagonist muscles have been suggested as the main risk factors for injuries in the lower extremities, lower extremity muscular function is important[21–23] and the return of muscle strength to pre-injury level is a criterion for ending rehabilitation[24]. In the results of the present study, there was no significant difference in knee extension, flexion, and knee extension/flexion ratio between both groups. Frisch et al.[25] also reported that there was no difference in muscle strength before and after injury in soccer players, which was similar to the results of the present study. This is thought to be because the main active muscles during a soccer game are the quadriceps muscles and hamstring, and thus, emphasis was placed on lower extremity muscle strengthening exercise to prevent re-injury.

The present study has limitations. Only one high school soccer team was analyzed in the present study. Moreover, player position, severity of injuries, duration of rehabilitation, return period after rehabilitation treatment in the lower extremity injury group, and standard values for aerobic exercise capacity, anaerobic power, and knee isokinetic muscular function among high school soccer players were not considered. However, the present study should provide basic data for creating post-injury training programs for high school soccer players with lower extremity injuries.

In conclusion, the results of the present study revealed differences in aerobic exercise capacity with respect to cardiorespiratory function and anaerobic threshold and anaerobic power in terms of fatigue index between high school soccer players with lower extremity injury and a control group. However, there was no difference in knee isokinetic muscular function between the groups. Therefore, it seems necessary to establish training programs that can maximize aerobic and anaerobic exercise capacity for soccer players with lower extremity injuries.

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