—**Report on Experiments and Clinical Cases**—

Anterior Cruciate Ligament Injuries among Wakeboarders: A Case Report

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Abstract

No previous cases of anterior cruciate ligament (ACL) injuries sustained during wakeboarding have been reported. We report on a case involving an ACL injury sustained during wakeboarding.

A 27-year-old man sustained an injury while attempting a wakeboarding maneuver (a heelside back roll, consisting of a jump and simultaneous roll toward the heel side). He failed to complete his roll before landing, striking the water with his right shoulder foremost, then plunging underwater. When his wakeboard struck the water, his left knee was sprained by the rotational force exerted by the board. The patient was diagnosed with an isolated ACL injury and underwent arthroscopic ACL reconstructive surgery.

The board used in wakeboarding is wider and subject to greater water resistance than that used in water skiing. The feet of the wakeboarder are firmly attached by binding boots to a board, laterally with respect to the direction of motion, impeding easy separation of the board from the feet in the event of a fall. Thus, wakeboarding conditions would appear to put wakeboarders at particular risk for ACL injuries. These conditions need be assessed from a medical perspective in order to devise ways to minimize the risk of such injuries.
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Key words: anterior cruciate ligament, wakeboarding, sports injury

Introduction

Injuries involving the anterior cruciate ligament (ACL) of the knee are relatively common in many sports. Athletes who have suffered ACL injuries often encounter difficulty resuming athletic activities, due to the resulting instability of the knee. Such injuries sometimes prevent athletic activity altogether. Establishing ways to treat and prevent ACL injuries is a key topic in sports medicine. However, due to the differing performance characteristics of specific sports, each sport requires different specific methods of treating and preventing ACL injuries. This means determining the risk factors for ACL injuries by analyzing the specific mechanism likely to cause such injuries in a specific sport. In basketball[1,2] or alpine skiing[3–7], sports in which ACL injuries are particularly common and cases of treatment numerous, the analysis of the mechanism of injury has

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Fig. 1 MRI (3 D-FT) findings at the 15th day after injury (A) and arthroscopic findings during the operation (B).
A: No image features characteristic of ACL were visible from the sagittal view.
B: A completely ruptured ACL, retained in the femoral notch via the synovial sheath alone.

made steady progress.

In recent years, the relatively new sport of wakeboarding has become increasingly popular among young people. Wakeboarding is similar to waterskiing, a sport that involves a motorboat pulling a rider balancing and sliding along the surface of the water on a relatively thin board. The wakeboard riding style differs from the style required for waterskiing, but bears a close resemblance to styles observed in snowboarding, a popular winter sport. The feet of a wakeboarder are secured to the wakeboard by binding boots, oriented laterally with respect to the direction of motion. The combination of this riding style and the traction force exerted by the towrope presents the potential for new types of knee injuries.

We report herein on a case involving an ACL injury sustained during wakeboarding. No previous cases of ACL injuries sustained during wakeboarding have been reported. Our discussion of this case focuses on the specific mechanism that typically results in knee injuries in wakeboarding.

Case Report

On August 20th, 2000, a 27-year-old man attempted a wakeboarding maneuver known as the heel-side back roll, which involves a jump and a simultaneous roll toward the heel side. He failed to complete his roll before landing, striking the water with his right shoulder foremost, then plunging underwater. Immediately after his wakeboard struck the water, his left knee was sprained by the rotational force exerted by the board, which was firmly bound to his feet. The patient reported feeling a sharp pop in his left knee. Following his wakeboarding session, the individual felt pain and swelling in his left knee, but was able to walk home with a coldpad applied to his knee. He visited the clinic the next day. Some 30 m*l* of blood was drained from his left knee, which had swollen considerably by this time. X-rays failed to pinpoint a problem. On August 24th, when the patient visited the clinic a second time and 20 m*l* of blood was drained from his left knee again, ligament damage was suspected, at which time he was introduced to our clinic.

Our clinical observations indicated no unusual swelling of his left knee or limitation in the range of motion. A positive Lachman test led us to suspect an anterior cruciate ligament (ACL) injury. In MRI findings, no image features characteristic of ACL were visible from the sagittal view (**Fig. 1A**), nor was

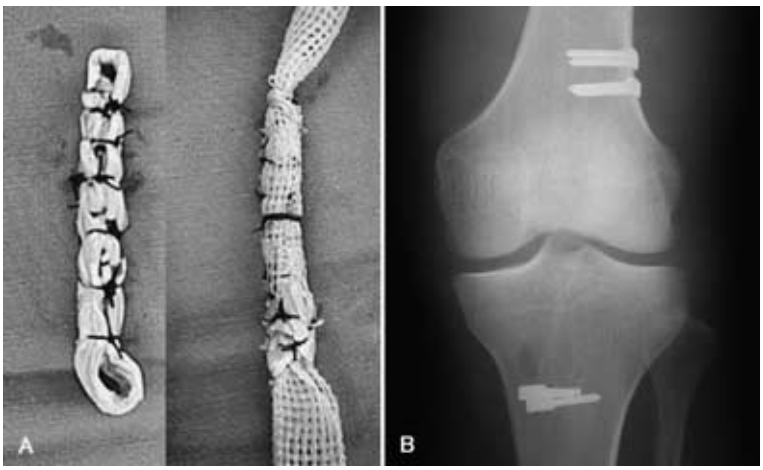

Fig. 2 Substitutes for ACL (A), and a postoperative X-ray photograph (B).
A: A composite graft with four strands of semitendinosus and gracilis tendon (STG) and woven polyester (Leeds-Keio) tightly sutured to their surface.
B: A graft was passed through tibial and femoral bone tunnels, and fixed with double staples.

there any visible damage to the menisci. From the above, we diagnosed an isolated ACL injury. The patient underwent surgery on October 5, 2000.

Arthroscopic findings during the operation revealed a completely ruptured ACL proximally, retained in the femoral notch via the synovial sheath alone (**Fig. 1B**). The arthroscopic ACL reconstructive surgery procedure[8] involved the following steps: a composite graft with four strands of semitendinosus and gracilis tendon (STG) and woven polyester (Leeds-Keio) tightly sutured to their surface was passed through tibial and femoral bone tunnels, and fixed with double staples (**Fig. 2A, B**). Range of motion and isometric muscle strengthening exercises were begun the day following surgery. On the eighth day following surgery, half-squats with a brace were initiated as a closed kinetic muscle strengthening exercise. On the 14th day after surgery, the patient was permitted to bear his full weight while walking. The range of motion in his left knee at four weeks after surgery was −10° of extension and 140° of flexion. The patient regained the full range of motion in his left knee at eight weeks after surgery, at which time he was permitted to begin running. At 11 weeks after surgery, the strength of his left quadriceps femoris muscle was evaluated as 60.3% that of the uninjured side (Cybex 7000 system). The patient was permitted to resume simple wakeboarding, without maneuvers.

Fig. 3 MRI (3D-FT) findings at 4.5 months after operation showed a wide low signal line in the sagittal view.

An MRI taken on February 21, 2001 (4.5 months after surgery) showed a wide low signal line in the sagittal view (**Fig. 3**). At this point, the patient was

Fig. 4 MRI (3D-FT) findings (A) and 2nd look arthroscopy (B) at 1 year after operation.
A: MRI findings for a reconstructed ACL were excellent.
B: Second look arthroscopy showed excellent stability of the knee.

permitted to perform all wakeboarding maneuvers, including roll-jumps. On July 20th, 2001 (9.5 months after surgery), the patient achieved an 11th place finish in the All-Japan wakeboarding championship, metropolitan division.

At one year after surgery, MRI findings for the patient's reconstructed ACL were excellent (**Fig. 4A**), while 2nd look arthroscopy (**Fig. 4B**) showed excellent stability of the left knee. The patient did not experience pain in this knee during wakeboarding or at other times.

Discussion

There have been no previous reports of ACL injuries related to wakeboarding. However, this would appear to have more to do with the relatively recent popularity of wakeboarding than the benign nature of the sport itself [9]. ACL injuries are seldom seen in water-skiing[10,11], a sport that would appear, at first glance, to be quite similar to wakeboarding, since it involves a motorboat towing a rider balancing on boards over water. The key differences between wakeboarding and water-skiing are that the wakeboard is wider than water skis and hence subject to greater water resistance; and that the feet of the wakeboarder are attached to a board laterally, by binding boots, with respect to the direction of motion, and attached more firmly than on water skis, making it more difficult for the board simply to separate from the feet in the event of a fall.

Wakeboarding got its start around 1985, when a young surfer named Tony Finn began surfing on calm days by having a truck pull him from shore. The sport received its official name in 1988, by which time binding devices had been installed on the boards. However, at that time, the binding mechanism was a strap rather than the current boot binding, allowing the feet to slip easily from the board during falls. By 1993, wakeboarding styles had gone beyond mere slaloms (involving merely skating on the water) to include "flips" (corkscrew somersaults), and the binding devices had changed from straps to boots. The current style of wakeboarding emphasizes competition and daring maneuvers. However, this daredevil style poses certain risks: because the wakeboarders' legs are so firmly secured to the board by the boots, their knees are subject to tremendous impact and torque if the rider falls and the board twists out of control.

We present a composite photograph of the patient's maneuver, identical to the one in which he sustained his injury (**Fig. 5**). Before his injury, the patient had repeatedly attempted and failed to make

Fig. 5 A composite photograph of the patient's maneuver, identical to the one in which he sustained his injury.
A flip, called the heel-side back roll, involves catapulting in the air from the wake created by the motorboat and rolling 360° clockwise before landing. The patient landed on his right shoulder, his body plunging into the water with a clockwise roll as his board was halted by water resistance.

this flip. As the patient informed us, he was well aware of the risk of injury if this flip is not executed successfully. Called the heel-side back roll, this flip involves catapulting in the air from the wake created by the motorboat and rolling 360° clockwise before landing. In the patient's case, he had repeatedly failed to complete the roll before landing. In the incident that apparently caused his injury, the patient landed on his right shoulder, his body plunging into the water with a clockwise roll as his board was halted by water resistance. His left knee was subject to a significant internal rotational force, resulting in the ACL injury described herein.

There are three general types of ACL injuries, classified by the direction of the force applied to the knee and causing the injury: 1) the valgus-external rotation type; 2) the varus-internal rotation type; and 3) the hyper extension type[12]. Alongside the complex knee ligament injuries associated with type 1), certain numbers of ACL injuries alone of types 2) and 3) also occur. There have been several recent reports concerning injuries associated with varus-internal rotation. Since such injuries are non-contact injuries caused by the athlete's own momentum or force, they can occur in quite ordinary movements, such as simply landing on the floor after jumping for a ball in basketball. In this case, the antagonistic forces that result in injury are the contraction of the quadriceps femoris muscle and the fixed position of the foot on the court surface. Sports in which players commonly encounter internal rotational forces on their knees are also characterized by a high rate of ACL injuries.

It is worth noting that the winter sport of snowboarding features physical movements quite similar to those found in wakeboarding. As in wakeboarding, a snowboarder's feet are bound by boots laterally to the direction of motion. However, when both feet are attached to a board, the knees are generally protected from large rotational forces. For this reason, and perhaps also because the impact force at landing is less violent, ACL injuries appear to be relatively rare among snowboarders. The snowboard injuries reported to date have generally involved the upper limbs and ankles[13–15]. Very few ACL injuries have been reported.

In contrast to snowboarding, the landing surface (water) in wakeboarding is very close to horizontal. This results in significant impact force upon the knee at landing. And because the bindings are not released if the wakeboarder falls, the knee is subject to powerful rotational forces exerted by the board when it strikes the water. In this case, we know the specifics of the incident leading to the injury: The patient plunged into the water, while the orientation of the skateboard remained unchanged. ACL injuries resulting from such incidents appear likely to increase in the future.

The patient described in this report continues to wakeboard without problems. With regard to ACL injuries in wakeboarding generally, we believe the most effective approach will consist of preventive measures based on medical assessments, focusing on safety bindings and other areas.

Conclusions

We report on a case involving an injury of the anterior cruciate ligament (ACL) of the knee occurring during wakeboarding. Wakeboarding conditions would appear to put wakeboarders at particular risk for ACL injuries. For this reason, wakeboarding needs to be assessed from a medical perspective in order to devise ways to minimize the risk of such injuries.

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