

Immediate Effect of Quadriceps Kinesio Taping on the Anaerobic Muscle Power and Anaerobic Threshold of Healthy College Students

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Abstract. [Purpose] This study examined the effect of taping the quadriceps femoris muscles of healthy college students on anaerobic muscle power (AMP) and the anaerobic threshold (AT) to analyze the functional value of taping on athletic performance capacity. [Subjects] Thirty male healthy college students were enrolled in this study. [Methods] The study was performed from April to May 2010 (for a month). Kinesio tapes, 5 cm in width, were applied to quadriceps femoris muscles of participants. AMP and AT tests were conducted at a sports science research laboratory. The paired t-test was conducted to examine the significance of differences between before and after taping. [Results] Mean power, peak power, mean power/kg, peak power/kg showed significant increases after taping. The induction time of AT, and, VE, VO₂, HR, VO₂max at AT showed no significant improvements after taping, but RPE showed a significant improvement. [Conclusion] Taping of the quadriceps femoris muscles of healthy college students affected AMP but not AT suggesting that taping influences athletic performance capacity.

Key words: Kinesio taping, Anaerobic muscle power, Anaerobic threshold

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INTRODUCTION

Quadriceps femoris muscles, which are always used when young and healthy athletes engage in active and competitive sports, are damaged easily¹⁾. Quadriceps femoris muscle damage may affect the athletic performance capacity of persons²⁾. Therefore, various methods to protect the quadriceps femoris muscles and increase their functions have been studied. Taping is a good example^{3, 4)} of a preventive method. Is easy to use, offers stability to the joint during activity, prevents musculoskeletal system damage, and improves athletic performance. Therefore, taping is widely used in physical therapy and by healthy young athletes^{5, 6)}.

Taping significantly increases the muscle power of the quadriceps femoris when applied to patients with lower limb damage⁷⁾. However, studies on the correlation between Kinesio taping and muscle power of the quadriceps femoris in healthy young athletes are sparse and have tended to produce differing results^{3, 4)}.

Previous studies of healthy young athletes have evaluated peak torque using isokinetic dynamometry, and muscle activity using electromyography (EMG) and H-wave amplitude³⁻⁵⁾. However, these evaluation methods may provide results which differ from the actual muscle activities during exercise. Movement patterns during exercise, such as walking and running, are not static but dynamic, and these dynamic movements show bilaterality patterns⁸⁾. Moreover, the anti-gravitational biomechanical arrangement pattern

continuously changes in the lower limb joints²⁾. Also, the resistance pattern and the reaction force at the earth's surface are indicated by the resistance of the toe or sole and the reaction force at the surface against the resistance, respectively. (For example, a resistance pattern arises when the lower limb touches the ground during activities like walking or running, and a reaction force occurs when the toe (or back) hits an object such as a ball or when pedaling on a bicycle.) In contrast to this, isokinetic dynamometry equipment (e.g., Cybex) evaluates the unilateral pattern. Furthermore, resistance affects the ankle rather than the toe or the sole, and it has a limited capacity to depict the efficiency of functional muscle power because it does not occur frequently during exercise⁹⁾.

The anaerobic muscle power (AMP) and anaerobic threshold (AT) tests are useful tools for evaluating the effect of functional muscle activity and metabolic activity on the pattern of dynamic movement, compensating for the problem of isokinetic dynamometry¹⁰⁾. Since the AMP and AT tests have high correlations with isokinetic dynamometry, they can be used to evaluate whether muscle power increases. Anaerobic exercise capacity is defined as the capability to supply the energy necessary for muscle contraction through the phosphagen and glycolysis systems¹¹⁾. Thus, an improvement in AMP is expected to improve athletic performance by: protecting muscles from anaerobic activity during the initial phase of exercise, extending the time before AT onset, and (3) delaying muscle fatigue.

Generally, the level of AT and the maximum volume of minute oxygen consumption (VO_2max) are evaluated to test AT¹². Since individuals with high levels of AT and VO_2max can generate energy via the organic metabolic pathway even during high exercise intensity, such individuals can maintain a higher exercise intensity, because muscle fatigue is delayed¹³. Thus, these tests are thought to evaluate an individual's capacity for performing exercise. This study examined the effect of taping the quadriceps femoris muscles of healthy college students on AMP and AT, to analyze the functional value of taping on athletic performance.

SUBJECTS AND METHODS

This study had single pretest-posttest design and, was performed from April to May 2010 with 30 healthy male college students (mean age, 21.07 ± 0.86 years; mean height, 170.05 ± 3.61 cm; and mean weight, 63.21 ± 3.70 kg) as subjects. The participants were selected from among students who had not exercised for physical fitness within 6 months prior to the study, and who had no recent history of musculoskeletal disease in the lower limb joints. All participants provided their written informed consent to participate in this study prior to enrollment.

Kinesio tape (Kinesio Taping Co. Ltd, Japan), 5 cm in width, was applied to the quadriceps femoris muscles. Participants were required to bend their knees for rectus femoris muscle taping. The origin of the rectus femoris muscle, the anterior inferior iliac spine, was first palpated and taped, and Y-type Kinesio tape was then wrapped around the patellar area. Participants were required to bend their knees and extend toward external rotation for vastus medialis taping. First, the tape was attached to the superior shaft of the femur, which is the origin of the vastus medialis, and was then passed around the palpated medial patella to the tibial tuberosity, whereupon the taping was completed. Participants were required to bend their knees and extend toward internal rotation for vastus lateralis taping. In this extended position, tape was attached to the medial linea aspera, which is the origin of the vastus lateralis then wrapped around the lateral surface of the patella and was finally fixed to the palpated tibial tuberosity^{4, 14}.

AMP and AT tests were conducted in the Sports Science Research Laboratory of Kyungwoon University. A temperature of 22 °C and a humidity of 60% were maintained during the study to minimize changes in the participants' physiological responses to environmental factors. The participants were asked to wear short-sleeved shirts and pants. AMP and AT tests were performed before and after taping in the following sequence. The AMP test was performed prior to taping, and the AT test was conducted 7 days later, after the body had stabilized. Taping was applied 7 days later, and the AMP test was performed 7 days after tape application, and the AT test was performed 7 days later. This sequence was followed so that muscle fatigue caused by previous exercise did not affect the study results.

The Wingate ergometer (Wingate Excalibur Sport, Lode BV Groningen, The Netherlands) was used to assess AMP^{15, 16}. The participants were asked to sit on the

ergometer and place their feet on the pedals, to which their feet were fixed. The initial posture for measurement required all participants to maintain their body angle at a 75-degree inclination, with a 10-degree angle between the handle of the bicycle ergometer and the elbow. The each participant was set as $0.8 \times$ body weight (in Nm), the figure for adult male athletes. The participants sat on the ergometer and warmed up for 3 minutes at 60 rpm and 100 W to establish a heart rate of 120–125. A 5-second countdown was used to signal to the participants to pedal with all of their strength for 30 seconds immediately after the command "Start." After 30 seconds, the participants were permitted active rest for 10 seconds at 60 rpm and 100 W. Verbal encouragement was given to the participants to exert maximum effort¹⁷.

For the AT test, VO_2max was measured as an index of cardiorespiratory fitness on a motor driven treadmill using the Bruce protocol, as described in the American College of Sports Medicine¹⁸ guideline. Specifically, the speed of the treadmill was initially set at a comfortable walking speed of 1.0–1.7 mph with a 10% grade. Speed and grade were then increased every 3 min until volitional exhaustion.

Oxygen consumption (VO_2) was measured using the standard breath-by-breath technique for pulmonary gas exchange variables (Metabolic Gas Analyzer System; Quark b2, Cosmed, Italy), and the exercise heart rate was measured using 12-lead electrocardiography (Quinton Q-4500, Bothell, WA, USA). The AT was determined by analyzing the ventilatory equivalents of O_2 (VE/VO_2) and CO_2 (VE/VCO_2). AT is considered to have been reached when VE/VO_2 presents a greater proportional increase than VE/VCO_2 ¹². VO_2max was defined as the highest oxygen consumption attained at the moment of exhaustion¹⁹. During the incremental exercise test, the rate of perceived exertion (RPE, Borg scale) was measured. RPEs were reported by the participants at the end of each stage in response to the question, "How hard did you work in this exercise?" The participants rated their RPE while looking at a printed copy of the Borg scale. This self-reported scale is graded from 6 to 20 and uses descriptive cues for each category of exertion within a scale ranging from "very, very light" to "very, very heavy"¹¹. In order to strictly define whether participants reached their VO_2max , at least 2 of the following 4 criteria had to be met: a respiratory exchange ratio of >1.15 , a rate of perceived exertion greater than 17 on the original category scale, volitional exertion, and achievement of age-predicted maximal heart rate. Study participants were verbally encouraged to exercise up to exhaustion during the test.

General characteristics of the participants were analyzed using descriptive statistics. The paired t-test was used to examine the significance of differences between pre- and post-taping. All statistical analyses were performed using the SPSS program (SPSS 12.0KO for Windows, SPSS, Inc., Chicago, USA), and statistical significance was accepted at values of $p < 0.05$.

RESULTS

The mean power, peak power, mean power/kg, and peak power/kg showed a significant increase following

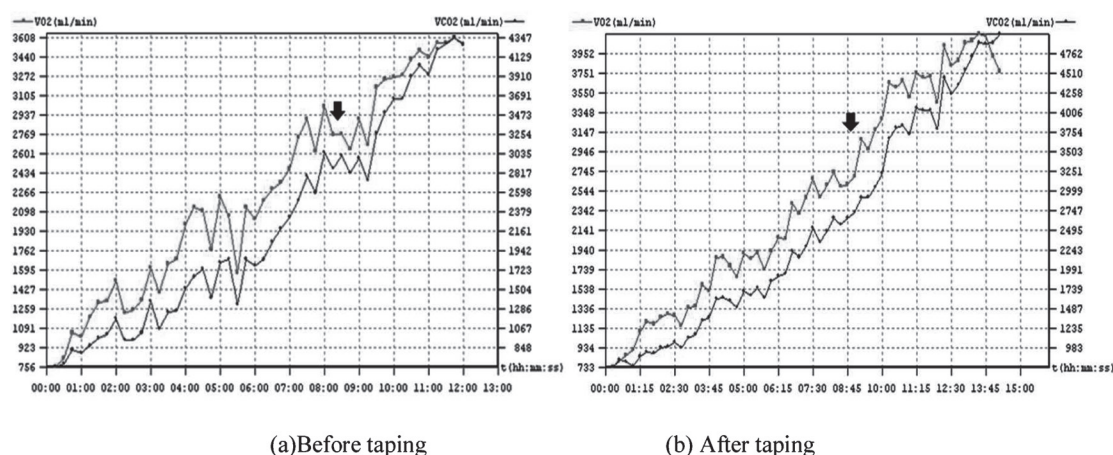


Fig. 1. AT and VO_2max change before and after taping. AT and VO_2max difference were not statistical significant but tended to increase (black arrow).

Table 1. AMP test results before and after taping

Variable	Before taping	After taping
Mean power(W)	579.9 ± 6.1^a	$586.7 \pm 30.8^*$
Peak power(W)	812.9 ± 13.4	$815.8 \pm 11.6^*$
Mean power/kg(W)	9.1 ± 0.8	$9.2 \pm 0.7^{**}$
Peak power/kg(W)	12.8 ± 0.8	$12.9 \pm 0.8^*$

^a: Mean \pm Standard Deviation, *: $p < 0.05$, **: $p < 0.01$

Table 2. AT test results before and after taping

Variables	Before taping	After taping
Reaching time of AT(sec)	472.8 ± 29.1^a	493.5 ± 24.1
VE (l/min)	68.6 ± 4.6	64.9 ± 6.5
VO_2 (ml/min)	2924.4 ± 323.1	3016.0 ± 562.6
HR (bpm)	139.5 ± 7.1	137.7 ± 7.1
RPE (score)	14.1 ± 1.0	$13.0 \pm 0.8^*$
VO_2max (ml/kg/min)	49.9 ± 4.2	50.8 ± 5.1

^a: Mean \pm Standard Deviation, *: $p < 0.05$, **: $p < 0.01$, VE: Ventilation, VO_2 : Oxygen Uptake, HR: Heart Rate, RPE: Rate of Perceived Exertion, VO_2max : Maximal Oxygen Uptake.

the application of tape according to the AMP test results ($p < 0.05$, Table 1). Although the time of AT onset, and VE, VO_2 , and HR at AT showed no significant improvements in response to taping ($p < 0.05$), RPE showed a significant improvement at AT ($p < 0.05$). At the maximum exercise capability, measured after passing AT, VO_2max did not show a significant improvement, but exhibited a tendency to increase ($p > 0.05$) (Table 2, Fig. 1).

DISCUSSION

Recent studies have described the power of the lateral muscle with single taping using Cybex for the rectus

femoris muscle of healthy young athletes^{3, 4}). However, the movement patterns while performing general exercise were shown to be dynamic, bilateral⁸). Muscle group recruitment patterns depend on coordination of a synergist muscle, neuromuscular control, and adaptation²⁰). When evaluating the increase in muscle power, it is necessary to consider the entire neuromuscular system rather than focus on a single muscle. Significantly increased muscle power is influenced by the duration of induction of maximal muscle tension. Active movement mostly decreases muscle activation since the muscle becomes anaerobic, resulting in muscle fatigue. This point of time is defined as AT, which indicates that exercise intensity is at the point where the blood lactic acid level begins increasing continuously as pure aerobic exercise turns into anaerobic exercise¹²). Thus, AMP improvement may improve athletic performance capacity by delaying the onset of AT.

In this study, the above-mentioned factors were considered while the effect of taping on AMP/AT was evaluated. Taping was applied to the rectus femoris, vastus medialis, and vastus lateralis muscles of both legs. To evaluate the effect of taping, bilateral patterns were used in the bicycle and treadmill exercises while the participants exercised, and the functional AMP/AT effect was identified. The Wingate anaerobic test (WAnT) was used to define subjects anaerobic muscle power. In previous studies, the WAnT has been extensively used to examine anaerobic exercise ability, and sports practitioners often use it to examine maximal power output and as a standard exercise task for analyzing athletes' responses to supramaximal exercise^{15, 16}). The AMP test is reported to improve as muscle power increases⁹). Kang (1997)⁹) found a significant correlation between Cybex values and AMP. Thus, a positive correlation (proportional relationship) is thought to exist between increases in AMP and Cybex values.

In this study, taping resulted in a significant improvement in AMP. In a previous study using Cybex, Fu et al.³) did not find a peak torque difference in the quadriceps femoris muscle, but they reported a significant increase in peak

torque at concentric 180 °/s of the quadriceps. However, Vithoulka et al.⁴⁾ reported a significant peak torque increase of the quadriceps femoris muscle of healthy non-athlete women. These different results are probably derived from the use of different study methods. We presume that Fu et al.³⁾ conducted the Cybex test with the general protocol (the mean peak torque of 1 or 2 movements with maximum muscle power) because they did not describe the method or intensity of the Cybex test in detail. In the study of Vithoulka et al.⁴⁾, the subjects warmed up for 10 min (including 3 sub-maximal and 2 maximal trials) and performed repetitive movements for evaluation in order to increase blood flow, increase myesthesia, and to provide adequate time for muscle and skin receptor stimulation. Vithoulka et al.⁴⁾ used the CON/CON and CON/ECC evaluation methods. During the first testing session (CON/CON), the quadriceps worked in a concentric mode for knee extension, but was relaxed for knee flexion. In the second session (CON/ECC), the quadriceps worked continuously in both movements, concentrically for knee extension and eccentrically for knee flexion, and showed a significant increase in muscle power of peak torque. These 2 testing modes reflect a substantial difference in muscular effort. Vithoulka et al.⁴⁾ assumed that this explained why Kinesio taping enhanced muscular performance only in the second testing mode, in which muscular effort was maximal both concentrically and eccentrically. Furthermore, Vithoulka et al.⁴⁾ applied taping to the vastus medialis and lateralis muscles in addition to the rectus femoris muscle, whereas Fu et al.³⁾ applied single taping to the rectus femoris muscle. As mentioned above, the mobilization pattern of muscles is the result of various cooperative activities of the quadriceps femoris muscle. In addition, a significant improvement of the peak torque value presumably occurred because the lower limb was aided by the associated muscles. Thus, the results of Vithoulka⁴⁾ suggest that a significant change in muscle power is achieved by providing adequate time for muscle activation, which leads to myesthesia and skin receptor activation by taping the quadriceps femoris muscle group, which increases coordination with associated muscles and by exerting muscular effort for maximum muscle power.

Given the different results of previous studies, several mechanisms may explain the significant improvement that was observed in the present study. First, as with the study of Vithoulka et al.⁴⁾, our study protocol presumably provided adequate muscle activation for tone and tension control, and sufficient time to stimulate the response of skin receptors during AMP evaluation. In addition, increased blood flow underneath the skin may have a significant influence on muscle metabolism. Taping creates wrinkles on the skin that increase blood flow¹⁴⁾, and the muscle's response to stimulus is increased by adequate warm-up time²¹⁾. Second, a continuous increase in the coordination capacity of associate muscles and antagonistic muscles between gravity and the reaction force at the earth's surface, and the effort to reach maximum anaerobic threshold occurred during the AMP test, thereby activating the proprioceptive sense and significantly increasing the capacity to control and integrate neuromuscular systems. Chang et al.⁵⁾ reported that taping applied to

the forearms of healthy college athletes did not significantly influence maximal grip strength, but tape applied to the area that requires the greatest sense of force for gripping showed a significant influence. We presume the effort required to align the lower limb muscle and to induce muscle power had a significant effect on the sense of effort; however, because this study did not cover muscular physiological evaluation, a follow-up study is necessary to support this hypothesis.

AT is the standard method for determining whether to continue exercising. Two methods are used to estimate AT: lactate threshold (LT) measurement using the level of blood lactic acid during exercise²²⁾, and ventilation threshold (VT) measurement using the volume of respiration gas. However, the LT test is inconvenient and painful because blood must be collected continuously during exercise. Recently, VT was shown to be more economic and easier to test than AT, and is now used as a standard test for AT. Moreover, VT is the most accurate and useful method for measuring the AT level¹⁰⁾. Anaerobic metabolism is initiated in a muscle when maintenance of exercise with aerobic metabolism is difficult beyond a specific exercise intensity, increasing lactic acid production, acidifying the blood, and raising carbon dioxide (CO₂) levels. Furthermore, bicarbonate (H₂CO₃) is created during this process when hydrogen ions (H⁺) enter the extracellular fluid from muscle cells.

AT is determined as the point when VCO₂ exceeds VO₂, that is, the respiratory exchange, VCO₂/VO₂, exceeds 1¹²⁾. In this study, AT was determined as described above. We evaluated the effect of tape applied to the quadriceps femoris muscle on the time required to reach AT, and VE, VO₂, HR, and VO₂max at AT. Significant improvements in these variables were not observed after taping, suggesting that taping a single muscle group in the quadriceps femoris muscle does not significantly improve systemic circulation or affect AT or VO₂max. However, the rate of perceived exertion (RPE), which indicates subjective exercise intensity, significantly decreased from 14.14 (hard) before taping to 13 (somewhat hard) after taping. This indicates that taping the quadriceps femoris muscle generated appropriate muscular tension, promoted blood flow, and eventually decreased fatigue due to exercise. Factors that affect AT such as oxidation at the cellular level, changes in muscular blood flow, and changes in the mobilization pattern of muscle fibers act as important factors. Although significant differences were not found before and after taping, AT and VO₂max showed a tendency to increase (Fig. 1). The decrease in RPE after taping during the performance of exercise at the same intensity as before taping is presumably the result of tape application. Therefore, further studies of various taping methods with more participants may show a significant effect on AT and VO₂max.

The ability of taping to increase muscle power in generally healthy individuals is affected by the direction in which the tape is attached to the skin²³⁾. Tape applied to the origin and insertion of muscles helps to relax muscle tone, whereas tape applied toward the direction of muscle contraction controls and increases muscle tone by stretching the insertion area²⁴⁾. Thus, the increases in AMP and RPE observed in this study WERE consistent with the general taping effect theory. This

study was limited to a single participant group and lacked a control group. Therefore, a future study will be necessary to investigate the correlations between the AMP and AT tests and Cybex in a control group. In addition, further study of muscular physiological variables and electromyographical variables is required to verify the results of this study.

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