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Knee Muscles Strength Can be Improved by Using an Elastic Band as an Assistive Device for Knee-Ankle Complex

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Background: There are various tools and methods used for strength exercise. Elastic bands, one of the resistance exercise tools, have been used for various purposes, including muscle strengthening; however, there is very little evidence supporting their efficacy. The study was performed to investigate the effect of knee-ankle elastic bands on knee muscle strength-related parameters according to sex in healthy adults.





Material/Methods: This was a cross-sectional study. Twenty-one participants (11 female and 10 male) were studied using a cross-over design. Isokinetic concentric knee extension and flexion strength was measured at 60°/s and 180°/s with and without application of a therapeutic elastic band in the shape of an "8", with knee flexion and ankle dorsiflexion. The variables related to muscle power automatically calculated in the protocol of the isokinetic system were compared according to sex and angular velocity.

Results: Peak moment (PM), PM/body weight, average power, total work, and the agonist/antagonist ratio, demonstrated significant improvement ($P < 0.05$) at both 60°/s and 180°/s "with" compared to "without" the elastic band according to sex.

Conclusions: The use of therapeutic elastic bands in the shape of a figure 8 with knee flexion and ankle dorsiflexion may be used as assistive devices for improving strength in muscles supporting the knee. Further high-quality studies are needed to assess the potential of elastic bands as assistive devices and not merely as exercise tools. Therapeutic elastic bands in the shape of an "8" with knee flexion and ankle dorsiflexion may be useful in sports activities.

Keywords: **Ankle • Knee • Muscle Strength • Stockings, Compression**

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Background

Sufficient muscle power in the lower extremities is necessary for adequate function in the activities of daily living [1]. Weakness of the quadriceps and hamstrings can lead to excessive internal rotation of the tibia, which can cause the genu valgum to produce knee moment. Impairment of distal motion, such as reduced ankle dorsiflexion in the exercise chain, can cause the genu valgum to reduce activation of the quadriceps [2-4]. Weakened quadriceps and hamstrings can limit the normal movement of the knee joint, reduce functional movements of the body, and contribute to the progression of diseases such as knee osteoarthritis [5,6].

It can be used as a therapeutic intervention for various disorders that occur due to muscle weakness around the knee joint. In general, strengthening exercises can be performed using a wide variety of tools, such as isotonic weight training and isokinetic exercises. A customized elastic band can be used as a muscle-strengthening exercise tool by providing resistance to the muscles around the joint for reducing the symptoms of the knee joint. Moreover, the use of elastic bands, which are economical and safe, has also been recommended as an assistive device [7]. The main goal of exercise using an elastic band is to take advantage of the resistance exerted by the band. Resistance exercise using elastic bands, which has been used as a clinical device since the 19th century, has been reported to induce muscle activation, leading to improved muscle power and endurance, as well as enhanced exercise capacity and quality of life [8-10].

In previous studies, an elastic band was applied to the lower extremities of stroke survivors to determine whether it could induce changes in gait. The results demonstrated that the movement of muscles around the joint were assisted by the band, resulting in significant improvement in gait cadence [3,11,12]. However, few studies have investigated such uses of elastic bands. Furthermore, few previous studies have applied an elastic band to a single joint, such as the hip or ankle, to explore its effect on balance and gait [12,13]. None have applied an elastic band to 2 joints, particularly on the knee while maintaining a state of dorsiflexion of the ankle, which could provide even more effective assistance [14].

Therefore, the present study investigated changes in knee muscle strength-related parameters resulting from the application of elastic bands as assistive devices in the knee-ankle joints of healthy adults. The hypothesis of this study was that knee muscle strength will be significantly increased through knee-ankle complex assistance using an elastic band.

Material and Methods

Participants

Volunteers were recruited for this study through an online bulletin board posted at A University, South Korea. Inclusion criteria were: (1) healthy adults in their 20's, (2) no history of knee pain for the prior 6 months, (3) no systemic disease that can cause musculoskeletal problems, (4) no deformity or abnormal function that can affect the movement of knee joint, and (5) abstinence from physical exercise for 48 h prior to the examination. Exclusion criteria were: (1) excess alcohol consumption 3 times or more per week, (2) use of protein supplements or steroid medications for increasing muscle mass, (3) extreme obesity or very low weight, and (4) inability to complete the experimental procedure.

Of the participants, 10 were men and 11 were women, and all were right-foot dominant. The mean ages of the men and women were 23.60 years (3.34) and 22.45 years (2.38), respectively. Men had a mean height and weight of 174.70 (5.77) cm and 80.20 (10.28) kg, respectively, while these measures in women were 162.45 (4.76) cm and 56.55 (15.08) kg, respectively.

Ethics

This study was approved by the Institutional Review Board of Kyungnam University and all participants provided informed written consent after receiving an explanation of the study purpose and procedures.

Sample Size Calculation

For sample size, the average power value of the knee extensor, one of the main dependent variables of this study, was calculated based on a previous study [15]. A retrospective sample size calculation was performed; the matched paired *t* test hypothesis was used to compare mean differences within a group. The α -value was set at 0.05 (2-tailed test) and the power was set at 80% (G^* power 3.1.7, Kiel, University, Germany). The sample size required for a paired *t* test was calculated as 7 participants with an actual power of 88.1%.

Protocol

The present study had a cross-over design. General information, including age, sex, height, weight and dominant foot, was collected through a brief interview with each participant. Isokinetic concentric knee extension and flexion strength was measured at 60°/s and 180°/s using an isokinetic device "with" compared to "without" the elastic bands on the knee-ankle joint.



Figure 1. Isokinetic muscle strength measurement with elastic band.

The elastic bands were applied to the knee-ankle joint as described in a previous study [3]. The elastic bands were applied in the shape of a figure 8, with knee flexion at 90° and dorsiflexion of the ankle joint at 5-10° (Figure 1). The elastic band was pulled sideways to be sufficiently wide to cover the knee joint and then tied crossing over the medial epicondyle in the center and, after making knots on the tibia head and the fibula head, it crossed the front side of the tibia. The elastic band was applied to embrace the knee joint; it was then pulled from the medial side of the plantar outwardly and tied. Green elastic bands (Thera-Band 2M level 3, Thera-Band, Malaysia) were used in this study.

For measurement of isokinetic concentric knee extension and flexion strength at 60°/s and 180°/s, an isokinetic device was used. The participants were seated maintaining 90° knee flexion after their thighs, shins, and pelvises were completely immobilized on the device seat. Complete extension of the knee was considered to be 0°, while 90° knee flexion was regarded as a parameter of knee flexion, and the lower extremity, where the elastic band was applied, was forced into 90° flexion to completely lower the knee joint during isokinetic muscle strength measurement. In consideration of muscle fatigue, a 1-h break was permitted between the measurements (with or without application of the elastic bands on the knee-ankle joint). All experiments were performed in a quiet room to minimize possible effects from the external environment.

Isokinetic Measurements

The Biodex isokinetic system (VI Pro, Biodex Medical Systems, Inc., NY, USA) was used to measure isokinetic concentric knee extension and flexion strength. The measurements were performed in accordance with the procedures suggested by the manufacturer (Biodex Medical manual, 1993).

Before starting the measurements, stretching was performed to prevent injury and measure the maximum muscle strength. Strength was measured bilaterally at 60°/s and 180°/s, incorporating gravitational correction. Measurement was of the reciprocal consecutive type, with 4 repetitions at 60°/s and 20 at 180°/s. Verbal encouragement was provided.

Statistical Analysis

Statistical analysis was performed using SPSS version 18.0 (IBM Corporation, Armonk, NY, USA). Data regarding general information of the participants are expressed as mean (SD) or mode (percentage). The outcome parameters consisted of the PM, PM/kgbw, average power, total work, and H/Q ratio. Differences in isokinetic concentric knee extension and flexion strength-related parameters between “with” and “without” use of the elastic band in females and males, respectively, were compared using the paired *t* test. The level of statistical significance was set at $\alpha=0.05$.

Results

Knee Extensor at 60°/s

Isokinetic speed on the dominant side knee extensor and flexor at the 60°/s in females revealed that peak moment, peak moment/body weight, average power, and total work were significantly higher with elastic band than without ($P<0.05$). The sides of agonist/antagonist ratio were the same. Also, the non-dominant side showed the same results as the dominant side (Figure 2A, 2B).

In males, peak moment, peak moment/body weight, average power, and total work of knee extensor and flexor of dominant side were significantly higher with the elastic band than without ($P<0.05$). In addition, average power and total work of extensor of the non-dominant side were significantly higher with the elastic band ($P<0.05$). Moreover, peak moment, peak moment/body weight, average power, and total work of flexor in the non-dominant side were significantly higher with the elastic band ($P<0.05$). Both sides of agonist/antagonist ratio were the same (Figure 3A, 3B).

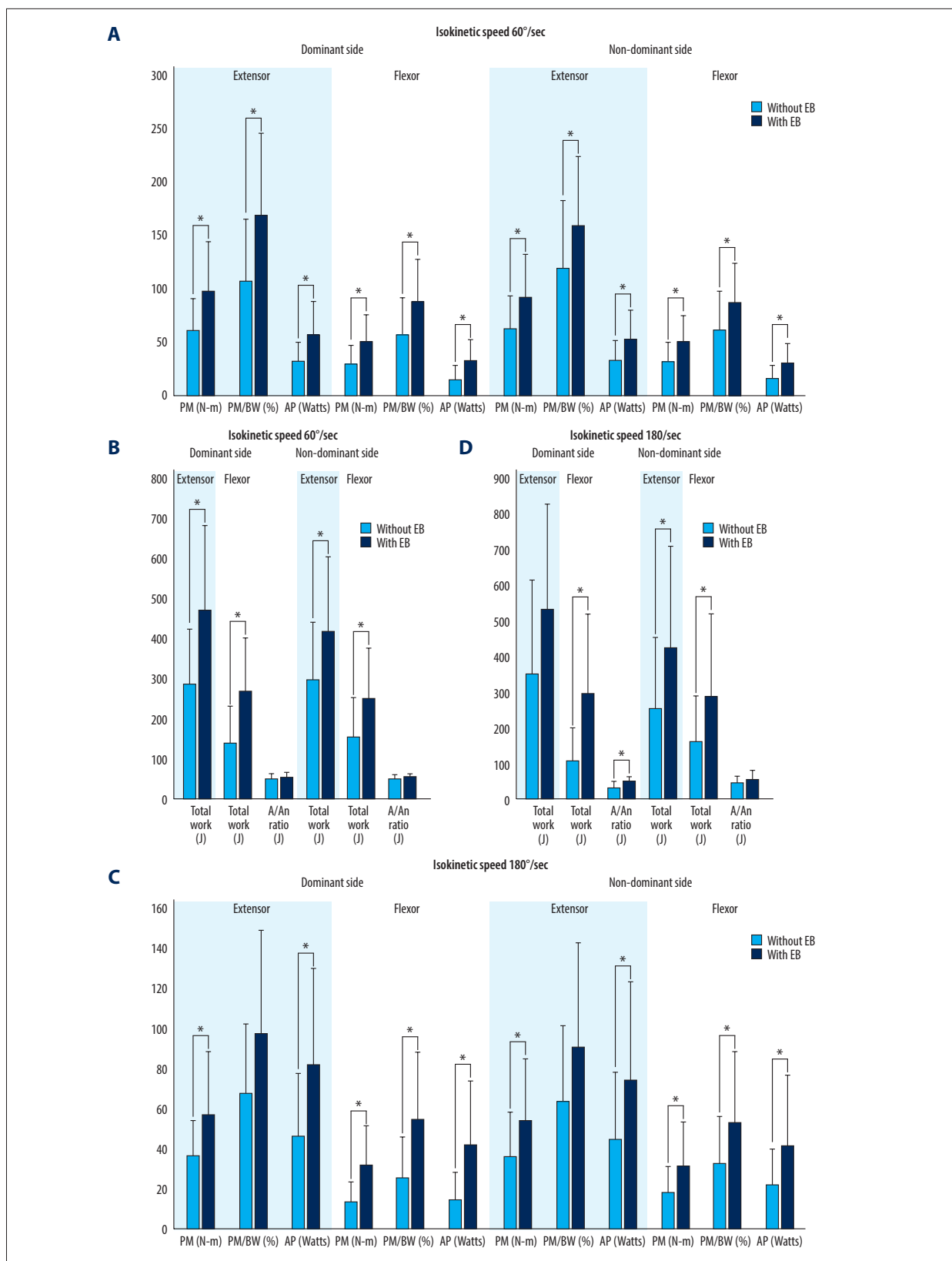


Figure 2. (A-D) Comparison of knee extensor and flexor between without and with elastic band in isokinetic muscle strength in female subjects.

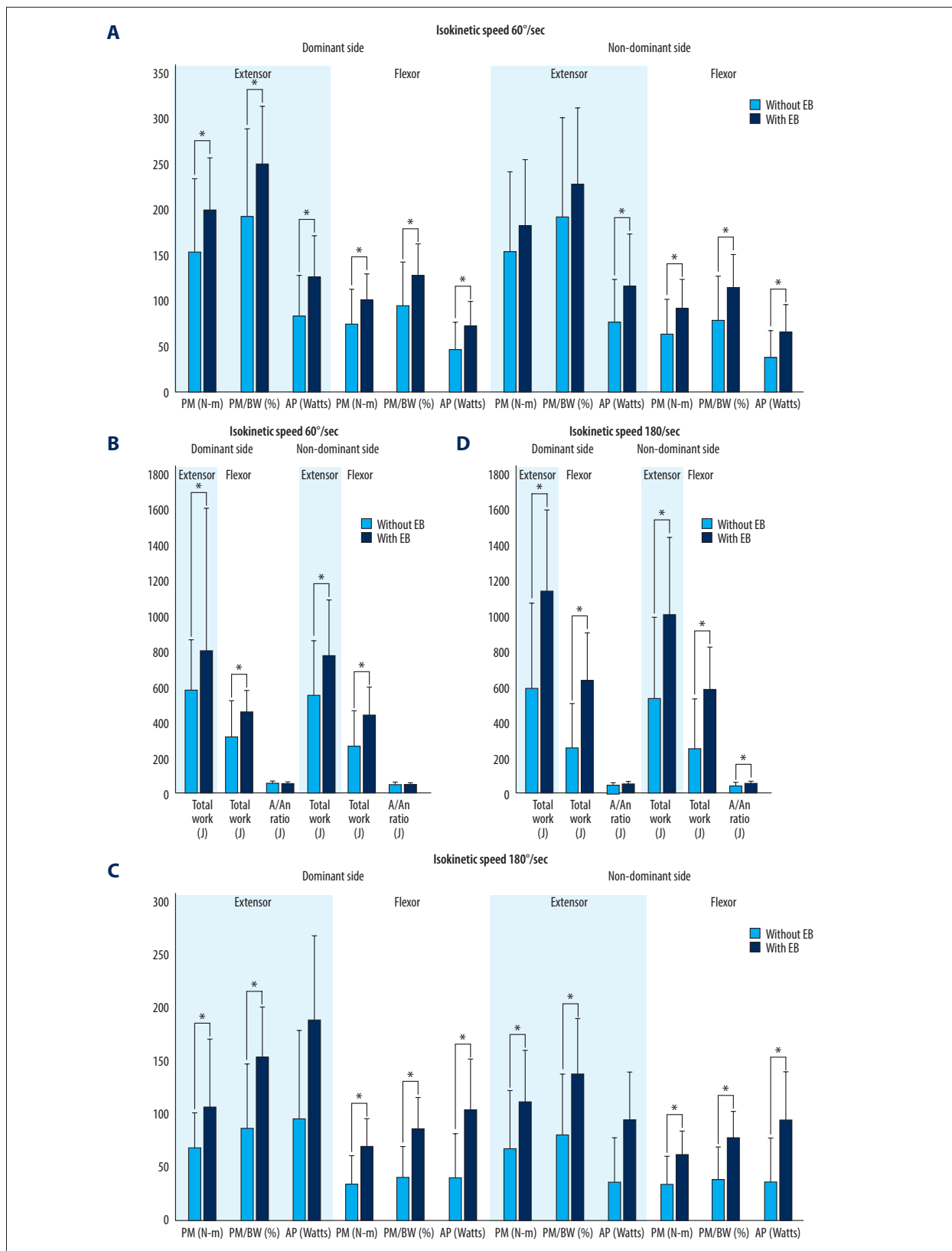


Figure 3. (A-D) Comparison of knee extensor and flexor between without and with elastic band in isokinetic muscle strength in male subjects.

Knee extensor at 180°/s

With the isokinetic speed at 180°/s, the dominant side knee extensor in females showed that the peak moment and average power were significantly higher with the elastic band than without (Figure 2C, 2D; $P < 0.05$). Peak moment, peak moment/body weight, average power, and total work of flexor were significantly higher with the elastic band ($P < 0.05$). On the non-dominant side, the aforementioned variables were significantly higher with the elastic band ($P < 0.05$) except for peak moment/body weight of the extensor. The agonist/antagonist ratio of the dominant side was significant higher with the elastic band ($P < 0.05$).

In males, on the dominant side the knee extensor and flexor had peak moment, peak moment/body weight, average power, and total work significantly higher with the elastic band than without ($P < 0.05$). In addition, peak moment and peak moment/body weight of the non-dominant side extensor were significantly higher with the elastic band than without ($P < 0.05$). The peak moment, peak moment/body weight, average power, and total work of the flexor were significantly higher with the elastic band than without (Figure 3C, 3D; $P < 0.05$).

Discussion

This study investigated whether the concentric strength of the knee joint can be improved when an elastic band was used as an assistive device to strengthen the knee-ankle complex. The concentric strength at 60° and 180° was evaluated using isokinetic measurement equipment, and the values of most peak moment, peak moment/body weight, average power, and total work in both males and females were significantly higher when elastic bands was applied in a figure 8 shape with dorsiflexion of the ankle maintained at 5-10° than without the elastic band.

The peak moment is the highest moment output of a joint produced by muscular contraction; it is one of the major factors of physical function [16]. In addition, the peak moment varies according to the subject's physical condition, and an objective assessment can be made when the peak moment is divided by body weight [7]. Davies et al reported that average power is a very valuable index in isokinetic muscle testing, which also verifies increased muscle power. The average power is the amount of total work divided by the time to complete the total work. This value is used to provide a measure of work rate intensity defined as total work divided by time; it also verifies increased muscle power [17].

Other studies of sex differences in muscle strength have reported that men generally have higher muscle strength than

women. The lower body muscles of women are generally 5-15% weaker than in men [18], and Trappe et al [2003] reported the women's muscle power was about 50% that of men's muscle power. In addition, a study by Skelton [1994] that compared muscle power per weight of knee extensors reported that females had power that was 64% that of men. In the present study, it was also found that, compared to women, men had higher peak moment, average power, and total work of the knee extensor and flexor with the elastic band applied compared to when it was not applied. The present study shows that the sex difference of muscle strength differs depending on the muscle mass of the skeletal system, the cross-sectional area of the muscle, the composition of the muscle fibers, and the number of muscle fibers. Nindl et al [1995] reported that male and female sex hormones produced sex differences in anoxic performance due to the direct effects of sex hormones. In addition, these sex-associated differences can affect muscle fiber composition, small cross-sectional areas of fast muscle fibers mobilized during high-intensity exercise, and low glycolytic enzyme activity [22].

In a study involving 30 healthy men as subjects, Mikaili et al [2018] investigated the difference between when the ankle was put in a neutral position for a straight leg raise test and when dorsiflexion was applied. Isometric contraction significantly increased when the knee was extended with dorsiflexion compared to when the knee was extended with the ankle joint maintained in the neutral position, and this may be explained by the connectivity of the excitatory reflex between the muscle attached to the front side of the tibia and the quadriceps [23]. The muscle receptor (muscle spindle and Golgi tendon organ) on the front side of the calf, which is related to the ankle dorsiflexor, exerts a strong neuro-excitation effect on the motor neurons in the quadriceps [14]. The results of the present study also demonstrated a significant improvement in isokinetic concentric knee extension and flexion strength when the elastic band assists the ankle dorsiflexion and knee extension, and can also be explained by the mechanisms suggested in previous studies.

Greater passive ankle dorsiflexion range seems to be associated with a better lower limb alignment during the single-leg squat [24], and paretic ankle dorsiflexion and knee extension torques were negatively correlated with the duration of self-sit to stand performance in stroke patients [25]. In addition, dorsiflexion ROM restrictions are associated with a greater risk of anterior cruciate ligament injury because in the squat posture the ground reaction force transmitted to the knee increases and the valgus displacement increases due to the decreased dorsiflexion angle [26]. Another study found that the variables of range of motion and strength of the hip and ankle are associated with squat depth, and ankle dorsiflexion with an extended knee and dorsiflexor strength were associated with

squat depth [27]. Restricted dorsiflexion range of motion can alter lower extremity landing mechanics, which predisposes athletes to injury [28]. An insufficient dorsiflexion angle can negatively affect the activity of the knee extensor and flexor.

The present results suggest that elastic bands assisted knee flexion and ankle dorsiflexion, which is expected to induce a sense of effort by causing tension in each muscle [29]. The sense of effort, which refers to the sensory experience of controlling the generation of power in a muscle, can strengthen the feedback-feedforward mechanism in the sensory system [30]. As a result, the motor neurons of the knee extensor and flexor are stimulated by the neurological signal (increasing sensory information) of sensory feedback on the knee flexor and ankle dorsiflexor provided by the elastic band and the tension, eventually leading to generation of muscle power. Based on neurological studies and proprioception neuromuscular facilitation, the degree of muscle contraction is affected by muscle(s) on the far side of the body, and the transmitted tension and power has been confirmed using signal radiation [31]. Because the activity of the ankle plantarflexor depends on the energy transmission of the ankle dorsiflexor [32], the elastic band, which is applied to assist the ankle dorsiflexor, can considerably improve muscle function in the knee extensors and flexors by transmission of energy to these muscles. Furthermore, muscle activation of the knee and the ankle increased the ratio of the agonist and antagonist, which provides joint stability, with the result being improved function of rolling and glide movements inside the joint cavity. Moreover, improved natural movement of the knee to help increase gait capability is expected, and the elastic band has the potential to be used as an assistive device for creating efficient gait for both sexes.

The H/Q ratio had been used for detecting muscle imbalance, knee joint stability, and muscle strength properties and functionality [33]. The conventional H/Q ratio suggests a concentric peak moment of hamstring to quadriceps during knee muscle force production [34], but it does not consider the eccentric moment during concentric contraction of the quadriceps. Thus, the functional H/Q ratio (Hecc/Qcon) suggests that the eccentric strength of the hamstring is important for knee joint stability during knee quadriceps concentric contraction [35]. The function H/Q ratio is a recent concept. The present study examined the change in concentric strength of knee extensor and flexor when a figure 8-shaped elastic band was applied to the knee-ankle complex as an assistive device. The conventional H/Q ratio is estimated as the result of the concentric strength of hamstring and quadriceps muscles. The results of the present study showed that only the dominant side of the flexor in females and the non-dominant side of the flexor in males were stronger with an elastic band than without. Further research is needed to assess the utility of elastic bands as an assistive device for functional H/Q ratio.

The application of dorsiflexion with knee movement creates more effective activation of knee muscles, and it has been employed as an intervention in musculoskeletal and neuromuscular disorders for functional improvement of the knee joint. The reason is considered to be the neuro-excitation effect, and in the present study the peak and average power values of the knee joint muscles were evaluated while maintaining a greater amount of dorsiflexion with use of elastic bands. Our results suggest that it can increase activity of knee joint muscles, and that more effective knee joint strengthening exercises can be induced through the method applied in this study.

The present study had a few limitations. First, this study included a relatively small number of participants. Further, the study results cannot be generalized because the participants only consisted of healthy adults in their third decade of life (ie, their 20s). Second, elastic bands with the same elasticity were applied to all participants even though each individual had different levels of muscle strength because of factors such as physical characteristics. Third, the peak moment of knee extensor at 60°/s without an elastic band was 2.5 times higher in men than in women, indicating a rather large difference, probably caused by differences in anthropometric characteristics and muscle mass according to sex and the small number of participants. Therefore, further high-quality studies are needed to confirm the effects of elastic band as an assistive device.

Conclusions

The present study verified significant increases in peak moment, peak moment/body weight, average power, total work, and agonist/antagonist ratio between the quadriceps, which is the agonist muscle, and the hamstring, which is the antagonist muscle, in “with” compared to “without” the elastic band as an assistive device to the knee-ankle complex to support the knee flexion and ankle dorsiflexion. Therefore, the elastic band method may be applicable in clinical settings to improve muscle strength-related parameters of the knee, which should prompt subsequent studies for verification. In the future, high-quality studies will need to continue to assess and confirm the potential of elastic bands as assistive devices, and not merely as exercise tools.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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