Effects of ankle exercise combined with deep breathing on blood flow velocity in the femoral vein

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Ankle exercises are commonly used to facilitate venous return in the lower extremity and to prevent deep vein thrombosis. Moreover, the respiratory cycle affects venous return. This study examined the effects of ankle exercise combined with deep breathing on the blood flow velocity in the femoral vein. Twenty healthy males (mean age 21.3 years), who had no medical history of lower extremity disease, were recruited for this study. The blood flow velocity in the femoral vein was measured while performing four exercise protocols: quiet breathing while resting (QR), deep breathing (DB), ankle exercise with quiet breathing (AQB), and ankle exercising combined with deep breathing (ADB). Using a Doppler ultrasound with an 8 MHz probe, peak blood flow velocities were collected for a 20 second period at the start of the inspiration phase in each protocol, three times. There were statistically significant differences in the peak blood flow velocity in the femoral vein with the four protocols ($p < 0.001$). The mean (SD) peak blood flow velocity in the femoral vein was as follows: QR 10.1 (4.2) cm/sec, DB 15.5 (3.9) cm/sec, AQB 20.7 (6.6) cm/sec, and ADB 26.5 (9.4) cm/sec. Post hoc analyses revealed significant differences between each of the four protocols ($p_{adj} < 0.01$). The mean peak blood flow velocity in the femoral vein was greatest with the ADB protocol, which implies that the ADB protocol may be useful to prevent the blood stasis in patients at risk of deep vein thrombosis.

Key words: Exercise, Breathing Exercises, Deep Vein Thrombosis, Femoral Vein, Blood Flow Velocity

Introduction


Since DVT is one of the risk factors for fatal pulmonary embolism, DVT prophylaxis has been emphasised in the rehabilitation setting (McNally et al 1997). Although several prophylaxis methods have been reported, mechanical methods of prophylaxis are commonly used. These mechanical methods include ankle exercises, leg lifting, the use of stockings, massage, intermittent pressure, passive range of motion, continuous passive motion, and electrical stimulation (Andrews et al 1993, MacKinnon 1983, Sochart and Hardinge 1999). The most common mechanical method to prevent DVT and to reduce the risk of pulmonary embolism is ankle exercise (O’Hagan and Kolvekar 2000, Vowden 2001). Encouraging active movement of the leg pre- and post-operatively is an important role for physiotherapists (MacKinnon 1983).

The muscle pump plays a major role in increasing cardiac output by increasing venous return during muscle contraction, which compresses veins and squeezes blood back towards the heart (Fleming et al 2000, Rowland 2001). Calf muscle pump failure is considered the main aetiological factor in patients with chronic venous ulceration (Orsted et al 2001, Yang et al 1999). Many studies have demonstrated that ankle and leg exercises have beneficial effects in increasing venous return in the lower extremities (Fleming et al 2000, MacKinnon 1983, McNally et al 1997).

Venous return is also influenced by the respiratory cycle in combination with thoracic and abdominal movements (Osada et al 2002, Willeput et al 1984). The Valsalva manoeuvre, which increases abdominal pressure, reduces the velocity of blood flow in the femoral vein in the supine position (Makin 1969). Previous studies have reported that the respiratory cycle affects venous return from veins in the lower extremity (Abu-Yousef et al 1997, Osada et al 2002, Teichgraber et al 1997).

Several studies have showed that femoral and portal venous blood flow velocities increase with expiration, and decrease with inspiration during deep breathing (Abu-Yousef et al 1997, Hsia et al 2000, Osada et al 2002, Teichgraber et al 1997). Conversely, the blood flow velocity in the pulmonary vasculature and superior and
inferior vena cava increases with inspiration (Hsia et al 2000). Inspiration increases the negative intrathoracic pressure, causing blood to be sucked into the thorax (Tkachenko et al 2001). Simultaneously, the abdominal veins are compressed as the diaphragm contracts. These changes in the intra-thoracic and intra-abdominal pressure with breathing help venous return because retrograde flow in the veins is hindered (Astrand and Rodahl 1986).

These findings led us to hypothesise that ankle exercise combined with deep breathing (ADB) increases the velocity of venous blood flow in the lower extremity. Although many studies have verified that pumping exercises and respiration patterns affect the velocity of venous blood flow in the lower extremity, no study has examined whether ADB facilitates blood flow velocity in the femoral vein. The purpose of our study was to determine the effects of ADB on the blood flow velocity in the femoral vein.

**Method**

**Subjects** Twenty healthy males were recruited from the Department of Physical Therapy at the Wonju Campus of Yonsei University. The selection criteria for the subjects were no history of surgery in the lower extremity, and no neurological, musculoskeletal, respiratory, or cardiovascular disease. The subjects averaged 21.3 years of age, 173.7 cm in height, 71.2 kg in weight. While resting, the mean respiration rate was 18.2 breaths/min and the mean heart rate was 78.8 beats/min.

**Procedure** Before the study, the principal investigator explained all procedures to the subjects in detail. Subjects signed consent forms, approved by the Y onsei University College of Health Science Human Studies Committee. Room temperature and relative humidity during the experiment were maintained at 22 to 24 degrees C, and 40% to 50%, respectively.

The blood flow velocity in the femoral vein was measured while performing four protocols: 1) quiet breathing while resting (QR), 2) deep breathing without ankle exercise (DB), 3) ankle exercise with quiet breathing (AQB), and 4) ankle exercise combined with deep breathing (ADB).

**Quiet breathing while resting (QR)** Subjects remained supine on the treatment table without a pillow throughout the measurements to maintain the probe position at the same site. The subjects were asked to relax completely. In order to minimise the changes in blood flow due to physical movement, all the participants were allowed to rest for 10 minutes while lying down with fully extended lower extremities. Heart rate and respiratory rate were measured in the quiet breathing while resting condition. We cleaned and shaved the skin in the area of the femoral vein and then measured the blood flow velocity in the femoral vein using a Dopplex Advanced Doppler® with an 8 MHz probe, using ultrasound transmission gel. The measurement point of the probe was placed over the femoral vein below the inguinal ligaments, with the probe...
Ankle exercise combined with deep breathing (ADB) was performed with fully extended hips and knees. A metronome was used to control the rate of breathing, as in the DB protocol. The inspiration and expiration phases alternated every 3 seconds for a 20-second period, and one cycle of the ankle exercise (active dorsiflexion and plantar flexion) was performed submaximally during expiration. The subjects practised the ADB exercise for five minutes. After adapting to the ADB protocol, blood flow velocity in the femoral vein was measured. To eliminate the potential for order effects, subjects rested for five minutes between tests until blood flow returned to the QR level. The same examiner measured the blood flow velocity throughout the study. We collected data for each protocol three times.

Data analysis Blood flow velocity in the femoral vein was determined using the Dopplex Reporter program. To quantify the data, we used MATLAB 5.3 to transform the data into ASCII form for analysis. We used averaged data for three readings of the peak blood flow velocity for 20 seconds in each protocol. SPSS Version 10.0 for Windows was used to analyse the averaged blood flow velocity in the femoral vein data. The intra-tester reliability of the peak blood flow velocity was assessed using the intraclass correlation coefficient (ICC). Repeated measures analysis of variance (ANOVA) was used to compare the average peak blood flow velocity in the femoral vein for each of the four experimental protocols. To assess statistically significant differences between each of the four protocols, paired t-tests were used. A Bonferroni adjustment was made for the multiple (6) variables analysed. Statistical significance was defined at $p_{adj} < 0.01$ (0.05/6).

Figure 2. Increase in the peak mean femoral venous blood flow velocity using the four protocols. All pairwise comparisons were significant ($p_{adj} < 0.05/6$)

QR = quiet breathing while resting
DB = deep breathing while resting
AQB = ankle exercise with quiet breathing
ADB = ankle exercise combined with deep breathing
Results

Figure 1 shows typical profiles of the blood flow velocity measured with the Dopplex Reporter program. The ICC (3,1) for repeated measurement of blood flow velocity in the femoral vein was 0.96 (95% CI = 0.91 to 0.98) for QR, 0.93 (95% CI = 0.87 to 0.97) for DB, 0.93 (95% CI = 0.87 to 0.97) for AQB, and 0.89 (95% CI = 0.80 to 0.95) for ADB. The average peak blood flow velocities of the 20 subjects were 10.1 cm/sec (SD 4.2) for QR, 15.5 cm/sec (SD 3.9) for DB, 20.7 cm/sec (SD 6.6) for AQB, and 26.5 cm/sec (SD 9.4) for ADB. ANOVA showed that there were significant differences in the average peak blood flow velocities in the four conditions. Post hoc analyses revealed significant differences between each of the four protocols ($p_{adj} < 0.01$) (Figure 2). The average peak blood flow velocity was greatest in the ADB protocol, and the velocities in the DB and AQB protocols were significantly greater than the velocity during quiet breathing while resting.

Discussion

The main mechanical methods for reducing venous stasis and preventing deep vein thrombosis are elevation of the legs, use of elastic stockings, passive movement of the foot, intermittent compression of the calf with pneumatic stockings, stimulation of muscle contraction with an electric current, and ankle exercise. That could be one reason why our result is higher than those of previous studies.

Although many previous studies have reported that ankle exercise, and deep breathing separately, increase the velocity of venous return in the lower extremity, our study is the first to determine the effects of ADB on the blood flow velocity in the femoral vein (Fleming et al 2000, Hsia et al 2000, McNally et al 1997, O’Hagen and Kolvekar 2000, Sochart and Hardinge 1999, Stannard et al 2001, Yang et al 1999).

The mean peak blood flow velocity in the femoral vein with the AQB protocol was 2.04 times higher than that of the quiet breathing while resting protocol. Previous studies did not mention the intensity of the ankle exercise. In our study, the mean peak blood flow velocity in the femoral vein with the AQB protocol was 2.04 times higher than that of the quiet breathing while resting protocol. Previous studies did not mention the intensity of the ankle exercise. In our study, the subjects performed ankle exercise submaximally. That could be one reason why our result is higher than those of previous studies.

Earlier studies reported that venous return is also influenced by the respiratory cycle (Osada et al 2002, Tkachenko et al 2001, Willeput et al 1984). Osada et al (2002) indicated that the femoral venous blood flow at expiration during deep respiration was significantly higher than in the normal and arrested conditions (without breathing in or out); it was about 1.7 times higher than during arrested respiration. In our study, the mean peak blood flow velocity in the femoral vein in the DB protocol was 1.53 times higher than in the QR protocol. These results suggest that DB is an alternate method of preventing venous stasis in the lower extremity. Patients who have severe pain or paralysis, which makes independent movements difficult, can be taught to use the deep breathing method instead.

A number of studies have examined the effect of ankle exercise on venous return (Fleming et al 2000, McNally et al 1997, Yang et al 1999). Fleming et al (2000) stated that the velocity of venous blood flow in the common femoral vein increased by 102.8% during foot pump exercise in the reverse-Trendelenberg (foot down) position. McNally et al (1997) studied the effect of active foot movement on venous blood flow in patients with total hip replacement. The authors reported that the mean maximum venous flow in the exercise group was 22% greater than the baseline value. Sochart and Hardinge (1999) also showed that the active combined movement (ankle flexion and rotation) produced the highest blood flow velocity, with a 38% increase in the mean venous blood flow velocity, and a 58% increase in peak flow in the 30° elevated leg position. It is not possible to directly compare the results of previous studies and those of our study, due to differences with respect to subjects, leg position, and intensity of the ankle exercise. In our study, the mean peak blood flow velocity in the femoral vein with the AQB protocol was 2.04 times higher than that of the quiet breathing while resting protocol. Previous studies did not mention the intensity of the ankle exercise. In our study, the subjects performed ankle exercise submaximally. That could be one reason why our result is higher than those of previous studies.

The major finding in this study was that the mean peak blood flow velocity in the femoral vein in the ADB protocol was the highest among the four protocols. The mean peak blood flow velocity in the femoral vein in the ADB protocol was 2.62 times higher than that of the QR protocol. This indicates that the AQB protocol, synchronized with the expiratory phase during the DB protocol, is a more efficient method of facilitating the blood flow velocity in the femoral vein than performing DB and AQB separately. Further studies are needed to identify whether the ADB protocol is indeed a more useful method in increasing the blood flow velocity in the femoral vein in patients with DVT. Previous studies have demonstrated that the blood flow velocity in the femoral vein increased significantly in the expiratory phase of deep respiration as compared with the inspiratory phase (Osada et al 2002, Willeput et al 1984). Willeput et al (1984) verified that venous return from the legs decreases during inspiration as a result of the rise in abdominal pressure. These results also support the idea of combining the two protocols (AQB and DB) (Osada et al 2002, Willeput et al 1984).

One limitation of our study was the validity of the measurement method. Abraham et al (1994) and Osada et al (2002) reported that the blood flow velocity in the femoral vein during arrested respiration, measured by Doppler ultrasound, was 10.8 (SD = 2.3) cm/sec and 0.14 (SD = 0.08) m/sec, respectively. In our study, the mean peak blood flow velocity in the femoral vein with the quiet breathing while resting protocol was similar to that in
previous studies. The mean peak blood flow velocity in the femoral vein with the quiet breathing while resting protocol was 10.1 (SD = 4.2) cm/sec in our study. Although there are some differences in the mean peak blood flow velocity in the femoral vein among studies, these could be due to differences in age, probe site, and anatomical variation between subjects.

An additional limitation of our study is testing order. The four exercise protocols were not performed in random order. The repeated testing in the same order for all subjects may contribute to cumulative increases of blood flow velocity in the femoral vein. However, the subjects rested for five minutes between exercises until the blood flow had returned to the quiet breathing while resting level. At the beginning of each test, we visually monitored the blood flow for 30 seconds to confirm that it had returned to the QR level. Therefore, differences in blood flow velocity in the femoral vein between the four protocols were unlikely to be due to order effects.

We showed that the ADB protocol noticeably increased the mean peak blood flow velocity in the femoral vein in healthy young subjects. However, the benefits of this protocol are yet to be confirmed in an actual clinical setting. To determine whether the ADB protocol is clinically beneficial, it must be studied in a range of patient groups. If the ADB protocol genuinely can increase the mean peak blood flow velocity in the femoral vein in patients at risk of DVT, it could be a practical intervention for preventing DVT.

Conclusion

This study showed that ADB significantly increased the mean peak blood flow velocity in the femoral vein. The results suggest that ADB might be recommended as a prophylactic method for patients at risk of DVT or blood stasis after cardiac, pulmonary, or orthopaedic surgery. It should be noted that our results are for healthy normal subjects. Further studies are needed to examine the efficacy of ADB in subjects at risk of DVT.

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