Ankle exercise and venous blood velocity

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Summary
Ankle exercise increases venous blood velocity while supine, but the effect of ankle exercise on venous blood velocity while sitting is not known. In this investigation, we test the hypothesis that venous blood velocity can be increased while sitting by repetitive dorsiflexion of the foot. Time-averaged peak velocity (TAPV) in the popliteal vein of 20 healthy male volunteers was measured by pulsed Doppler ultrasound at rest and during ankle exercise in the supine and sitting positions. Right popliteal vein TAPV while supine at rest was 11 cm/second (sec) (95% confidence interval [CI] = 9–13 cm/sec) and with ankle exercise it increased to 24 cm/sec (95% CI = 20–28 cm/sec) (p<0.0001). With sitting at rest, right popliteal vein blood TAPV decreased from 11 cm/sec to 3 cm/sec (95% CI = 2–4 cm/sec) (p<0.0001). With ankle exercise while sitting, right popliteal vein TAPV increased to 18 cm/sec (95% CI = 15–21 cm/sec) (p<0.0001). In conclusion, in both the supine and sitting positions, ankle exercise increased venous blood velocity, thereby transiently reducing a tendency toward venous stasis. Such ankle exercise might be useful in the prevention of stasis-induced deep venous thrombosis.

Keywords
Venous blood velocity, ankle exercise, economy class syndrome, deep venous thrombosis, popliteal vein, pulmonary embolism

Introduction
Early and frequent ambulation of hospitalised patients at risk of venous thromboembolism (VTE) is an important principle of patient care (1). However, many patients cannot be fully ambulatory after hospital admission or after surgery (1). Mechanical methods of thromboprophylaxis, which include graduated compression stockings, intermittent pneumatic compression devices and the venous foot pump increase venous flow and/or reduce venous stasis (1). These mechanical methods of thromboprophylaxis have been shown to reduce the risk of deep venous thrombosis (DVT) after general surgery (2), neurosurgery (2), elective hip arthroplasty (3), total knee arthroplasty (4, 5), and surgery for hip fracture (6), although they are generally less efficacious than anticoagulant thromboprophylaxis (1, 7). Previous investigators have shown that ankle exercise increases venous blood velocity while supine (8–10). Ankle exercise might be a useful addition to the methods of mechanical thromboprophylaxis in hospitalised patients if it is confirmed to increase venous blood velocity while supine. It might also be useful in patients confined to a chair for long periods of time if it can be shown that ankle exercise increases venous blood velocity while sitting.

Even in healthy adults, immobilisation in a chair for long periods of time can lead to DVT. One such setting is long-distance travel, often in a cramped position. Thromboprophylaxis has been reported with various modes of transportation (11–13). Prolonged periods in cramped quarters, even if not traveling, can lead to pulmonary embolism (PE) (14). The term "economy class syndrome" was introduced in 1988 (15), but has since been replaced with “flight-related DVT” in recognition of the fact that all travelers are at risk, irrespective of class of travel (16).

There is a strong and significant association between prolonged air travel and PE or DVT (17). Flight duration between 3–18 hours appears to be a risk for DVT (18–22). The risk of fatal PE for air travel longer than eight hours was 1.3 per million travelers (23). Some data suggest that only plane, car, bus or train travel longer than 10 hours is associated with a risk of VTE (24). A prominent cause of DVT during airline travel would appear to be venous stasis. Venous blood velocity and flow decrease while sitting (25, 26). Popliteal flow progressively decreases over a...
period of 100 minutes (min) during quiet sitting (26). Dehy-
dration has been considered as a possible contributing factor to
DVT during air travel, but did not explain coagulation activation
during air travel in one study (27, 28).

Venous blood velocity during ankle exercise while sitting has
not been measured. It has been shown, however, that foot exer-
cises performed against resistance for 30 seconds (sec) every
15–20 min over a 100-min period enhanced popliteal blood vel-
ocity and volume flow when measured with the subject sitting
motionless (not exercising) at selected time intervals during that
100-min period (26). In this investigation, we further examine
the effect of ankle exercise on venous blood velocity while su-
pine and the extent to which sitting decreases venous blood ve-
locity. We test the hypothesis that popliteal blood velocity can be
increased while sitting by repetitive dorsiflexion of the foot.

Methods

Time averaged peak velocity (TAPV) of blood in the popliteal
vein was measured by pulsed Doppler ultrasound in 20 healthy
normal male volunteers at rest and during ankle exercise in the
supine and sitting positions. The age of volunteers was 28 ± 3
years (mean ± SD) (range 23–33 years). Height was 174 ± 6 cm
(range 163–185 cm) and weight was 74.7 ± 12.4 kg (range
69.2–80.1 kg). The volunteers had no history of surgery in the
lower extremity, and no neurological, musculoskeletal, respir-
atory or cardiovascular diseases. The investigation was approved
by the hospital institutional review board. All volunteers gave
written informed consent.

Popliteal vein blood velocity

The TAPV was measured at rest in both the right and left popli-
teal veins during quiet respiration with the volunteer supine and
his head elevated 30°. Shoes and socks were removed. Right pop-
liteal TAPV was re-measured in the supine position while the
subject maximally dorsiflexed and plantarflexed his right foot at
an average rate of 62 flexions/min (95% confidence interval [CI]
60–64 flexions/min). After supine ankle exercise, the subject
rested 3–9 min.

While sitting, the right knee was flexed at 105° to 110°, with
the foot flat on the floor. In the sitting position, the angle between
the spine and thighs was no more than 90°. Measurements of
right popliteal TAPV were then obtained in the sitting position at
rest and during repetitive maximal dorsiflexion of the right foot
at 64 flexions/min (95% CI = 61–68 flexions/min).

Doppler ultrasonic recordings

Pulsed wave Doppler recordings in the popliteal veins were
made using a Philips iU22 ultrasound system (Bothell, WA,
USA) and L9–3 broadband linear array transducer with an ex-
tended operating frequency range of 9 to 3 MHz. The settings
gain, contrast, rejection) were optimised after initial evaluations
and then maintained constant. The threshold was maintained
constant at 50%. The site of sampling was guided by color flow
mapping to position the sample volume at the center of the color
signal and to create the smallest angle of insonation (between
45° and 60°) between the direction of blood flow and the Doppler
beam. Sample volume was preset and maintained at 2.0 mm.
Each Doppler flow signal was recorded on a compact disc and
hard copies were available for reference. Measurements of
TAPV were obtained from computer measurements obtained
from the recording system.

Table 1: Time-averaged peak venous blood velocity in
popliteal vein.

<table>
<thead>
<tr>
<th></th>
<th>Right supine rest Mean (95% CI) (cm/sec)</th>
<th>Left supine rest Mean (95% CI) (cm/sec)</th>
<th>Supine exercise Mean (95% CI) (cm/sec)</th>
<th>Sitting rest Mean (95% CI) (cm/sec)</th>
<th>Sitting exercise Mean (95% CI) (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Popliteal v. TAPV</td>
<td>11 (9–13)</td>
<td>8 (7–11)</td>
<td>24 (20–28)</td>
<td>3 (2–4)</td>
<td>18 (15–21)</td>
</tr>
</tbody>
</table>

TAPV: time averaged peak velocity; v, vein; CI, confidence interval. Differences between left and right time-averaged peak blood velocity were not significant. Differences between supine rest and sitting rest, and differences between rest and exercise were p< 0.0001.

Table 2: Time-averaged peak venous blood velocity at rest.

<table>
<thead>
<tr>
<th>Popliteal vs. supine (cm/sec)</th>
<th>Popliteal vs. sitting (cm/sec)</th>
<th>First author (Ref.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.8</td>
<td></td>
<td>Macklon (30)</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Macklon (29)</td>
</tr>
<tr>
<td>0.9*</td>
<td></td>
<td>Hitos (26)</td>
</tr>
<tr>
<td>10</td>
<td>6.5</td>
<td>Delis (25)</td>
</tr>
<tr>
<td>11 right</td>
<td>3 left</td>
<td>Present study</td>
</tr>
<tr>
<td>9 left</td>
<td></td>
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</tr>
</tbody>
</table>

*Time-averaged velocity, v=vein, right = right popliteal vein, left = left popliteal vein.
What is known about this topic?

- Venous blood velocity is decreased with sitting.
- Ankle exercise increases venous blood velocity while supine, but the effect of ankle exercise on venous blood velocity while sitting is not known.

What does this paper add?

- Repetitive dorsiflexion while sitting prominently increases blood velocity in the popliteal and common femoral veins.
- Ankle exercise while sitting might be useful in the prevention of deep venous thrombosis.

Statistical analysis

Chi-square test was used to assess differences of proportions (InStat version 3.0 GraphPad Software, San Diego, CA, USA). Ninety-five percent confidence intervals (95%CI) and standard deviation were calculated using calculator for confidence intervals of relative risk (www.sign.ac.uk/methodology/risk.xls).

Results

The TAPV while supine at rest did not differ significantly in the right popliteal vein and left popliteal vein, 11 cm/sec (95% CI = 9–13 cm/sec) compared to 8 cm/sec (95% CI = 7–11 cm/sec) (Table 1). With ankle exercise while supine, TAPV in the right popliteal vein more than doubled from a mean of 11 cm/sec at rest to 24 cm/sec (95% CI = 20–28 cm/sec)(P<0.0001) (Table 1, Fig. 1).

With sitting at rest, right popliteal vein TAPV decreased 73% from 11 cm/sec when supine to 3 cm/sec (95% CI = 2–4 cm/sec) (p<0.0001). With ankle exercise while sitting, right popliteal TAPV increased six times from 3 cm/sec to 18 cm/sec (95% CI = 15–21 cm/sec) (p<0.0001).

Discussion

In both the supine and sitting positions, ankle exercise increased popliteal vein blood velocity. Such ankle exercise would transiently eliminate a tendency toward venous stasis in the lower extremities with prolonged sitting. This may be particularly useful during prolonged travel in a sitting position, although we have no data to indicate the amount and frequency of ankle exercise that would be necessary to prevent stasis-induced DVT.

Previous measurements of TAPV in the popliteal vein in the supine position were reported as 6 cm/sec (29), 6.8 cm/sec (30) and 10 cm/sec (25), respectively. The values that we measured were similar (Table 2). In the popliteal vein while sitting, values of 0.9 cm/sec (time averaged velocity) and 6.5 cm/sec TAPV have been reported (25, 26).

Similar values of TAPV in the right and left popliteal veins indicate that our measurements were consistent. Relative changes of blood velocity are probably more important than absolute values for determining if ankle exercise effectively increases TAPV. Others showed that popliteal blood velocity while sitting with foot exercises against resistance increased 15% when blood velocity was measured after exercise was completed (26). We showed a six-times increase during ankle exercise while sitting. Blood velocity has also been measured in the common femoral vein during ankle exercise while supine. Kwon et al. showed a 104% increase in the common femoral vein with ankle exercise while in a supine position (10). Ankle exercise at only 15 dorsiflexions/min for 5 min caused common femoral blood velocity to increase 35% (31).

A strength of our investigation is that this is the first time, to our knowledge, that venous blood velocity during ankle exercise has been measured while sitting, and there are sparse data on venous blood velocity while sitting at rest (25, 26, 32). Our results are consistent with fractional changes of blood velocity reported by others with ankle exercise while in a supine position (10). In conclusion, ankle exercise increased venous blood velocity in both the supine and sitting positions. Such ankle exercise, by transiently and intermittently increasing blood velocity might be useful in the prevention of stasis-induced DVT.

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References