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REVIEW

Knee versus Thigh Length Graduated Compression Stockings for Prevention of Deep Venous Thrombosis: A Systematic Review

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Objective. Graduated compression stockings are a valuable means of thrombo-prophylaxis but it is unclear whether knee-length (KL) or thigh length (TL) stockings are more effective. The aim of this review was to systematically analyse randomised controlled trials that have evaluated stocking length and efficacy of thromboprophylaxis.

Method. A systematic review of the literature was undertaken. Clinical trials on hospitalised populations and passengers on long haul flights were selected according to specific criteria and analysed to generate summated data.

Results. 14 randomized control trials were analysed. Thirty six of 1568 (2.3%) participants randomised to KL stockings developed a deep venous thrombosis, compared with 79 of 1696 (5%) in the TL control/thigh length group. Substantial heterogeneity was observed amongst trials. KL stockings had a significant effect to reduce the incidence of DVT in long haul flight passengers, odds ratio 0.08 (95%CI 0.03–0.22). In hospitalised patients KL stockings did not appear to be far worse than TL stockings, odds ratio 1.01 (95%CI 0.35–2.90). For combined passengers and patients, there was a benefit in favour of KL stockings, weighted odds ratio 0.45 (95% CI 0.30–0.68).

Conclusion. KL graduated stockings can be as effective as TL stockings for the prevention of DVT, whilst offering advantages in terms of patient compliance and cost.

Keywords: DVT; Deep vein thrombosis; GCS; Graduated compression stockings.

Introduction

Graduated compression stockings (GCS) are a commonly utilised and effective means of mechanical thromboprophylaxis.^{1–3} Thigh length (TL) graduated compression stockings distribute their mechanical effect over a greater proportion of the lower-limb, thereby offering a potential advantage over shorter knee-length (KL) varieties. However, evidence to support this is inconclusive. Furthermore TL stockings are more difficult to apply and may lead to a more pronounced tourniquet effect over the upper thigh if

applied incorrectly or allowed to ruck after application.^{4–7} This tourniquet effect can potentially damage skin and reduce venous outflow, leading to increased potential for deep venous thrombosis. Conversely, when KL stockings roll down toward the ankle, the pressure gradient is not reversed, as pressure remains greatest at the level of the ankle due to the relative width of the stocking at the calf and the associated pressures generated by the portion of the stocking still located in the correct position. Other described advantages include patient preference and comfort.^{5,6,8}

We undertook to establish, by a systematic review of literature, the effectiveness of knee length elastic stockings in thromboprophylaxis in hospitalized patients and in high risk subjects travelling by air for more than 8 hours.

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Methods

Relevant studies published between January 1976 and June 2005 were identified through the MEDLINE, EMBASE, CINAHL and COCHRANE LIBRARY databases. The terms "stocking/s", "sock/s" and "hosiery/hosieries" were used in combination with the medical subject headings "thromboprophylaxis", "knee length graduated compression stockings", "thigh length graduated compression stockings", "thromboembolism" and "post-operative complications". Relevant articles referenced in these publications were obtained. Each article was critically reviewed to assess eligibility for inclusion in this meta-analysis (Table 1). Exclusion criteria were DVT not a study outcome, length of stockings not reported, review paper, patients reported in a duplicate publication, paper unavailable to authors. Randomised controlled trials comparing KL and TL compression stockings in hospitalized patients (including subjects undergoing orthopaedic, abdominal, urological, gynaecological, ENT, neurosurgical and gastrointestinal procedures) and amongst airline passengers were selected. Comparisons of deep venous thrombosis (DVT) incidence were made between patients assigned to KL or TL prophylaxis and were combined by meta-analysis. Analysis was performed on the combined group (hospitalised population for surgical procedure and air travellers) and the two groups separately. Analysis of populations on long haul flights was performed for effectiveness of KL stockings against no stockings to check their isolated performance. Odds ratios were calculated and a fixed effect-model employed, with tests for heterogeneity. Where heterogeneity was detected, a random effects model also was applied. In addition, meta-regression analysis was carried out to assess the relative benefit

Table 1. Inclusion criteria

- Randomised, controlled, prospective clinical trial on use of knee length/thigh length elastic stockings for thromboprophylaxis
- Use of objective diagnostic tests for determination of DVT. Duplex venous ultrasonography, contrast venography and fibrinogen uptake scan were used for the diagnosis of DVT.
- Studies where the end point was DVT in either below knee or above knee deep veins of leg.
- Use of blinded interpretation of diagnostic tests. Each positive diagnostic test was evaluated by two different radiologists unaware of reported conclusion of each other.
- Use of predefined criteria for abnormal test results. Positive duplex scan was defined where thrombus was seen and/or vein was not compressible. Positive venography was defined where the filling defect inside vein was seen. Positive fibrin scan was defined where excessive accumulation of radioactive fibrinogen in the deep vein was observed.
- Any size of study.

of knee length stockings on airline passengers versus hospitalized subjects. In a sensitivity analysis, 0.5 was added to each cell frequency for trials in which no event occurred in either the treatment or control group, according to the method recommended by Deeks *et al.*⁹ The analysis was carried out using Stata software running on a personal computer (Version 9 © Stata Corp 1984–2005, Texas, USA).

Results

Twenty-nine clinical studies were initially retrieved. Of these, 14 fulfilled the inclusion criteria (Table 2)^{7,10–18} and 15 studies were rejected (see web Appendix). In three trials^{16,17} no events were observed either in the knee length stockings or the control groups, and thus these trials could not contribute to the pooled odds ratio.

Hospital surgical patients

For the five trials of hospitalised subjects (Table 3), the odds ratio from a fixed effects model was 1.11 (95% CI 0.66–1.85, $z = 0.38$, $p = 0.7$), but there was significant heterogeneity ($\chi^2 = 13.5$, $df = 4$, $p = 0.009$). In a random effects model, the odds ratio was 1.01 (95% CI 0.35–2.90, $z = 0.01$, $p = 0.99$). Thus there was little evidence of difference between knee length stocking and thigh length subjects. On the basis of this analysis, there is 6% risk of developing DVT if subject is using KL stockings while that risk will decrease to 4% if subject uses TL stockings.

Long haul flight passengers

For nine trials of long haul passengers, DVT events were observed in six trials (Table 2). Overall, the odds ratio of risk of DVT in the six trials was 0.08 (95% CI 0.03–0.22, $z = 4.84$, $p < 0.001$), Table 4, and there was no evidence of heterogeneity.

Hospital patients and long haul flight passengers combined

The pooled odds ratio (calculable for only 10 of the 13 trials) for DVT was 0.45 (95% CI 0.30–0.68; $z = 3.78$, $p < 0.001$), indicating an overall 55% odds reduction of DVT if knee length stockings were worn compared to groups assigned to either thigh length or no stockings (Table 5). However statistical heterogeneity was observed among the studies ($\chi^2 = 34.7$, $df = 10$, $p < 0.001$). A trend in the direction of DVT risk

Table 2. Trials used for review

RTCs	Diagnostic test used	Knee length GCS group DVT %	Control/Thigh length GCS Group DVT %	Type of population studied
1 Porteous <i>et al.</i> ⁷	FUS	1/58 (1.7%)	3/58 (5.1%)	General surgical patients
2 Williams JT <i>et al.</i> ¹⁰	FUS	6/44 ^{*1} (14%)	6/44 (14%)	General surgical patients
3 Hui <i>et al.</i> ¹¹ THR	Venography	9/18 ^{*2} (50%)	6/22 (27%)	Orthopaedic patients
4 Hui <i>et al.</i> ¹¹ TKR	Venography	7/22 ^{*3} (32%)	21/32 (65%)	Orthopaedic patients
5 Howard <i>et al.</i> ¹²	Duplex	11/99 (11%)	8/195 (4.1%)	Breast surgery, oncology, ENT, urology, vascular, neurosurgery. And gastrointestinal surgery
6 Scurr <i>et al.</i> ¹³	Duplex	0/100 (0%)	12/100 (12%)	Long haul flight passengers
7 Belcaro <i>et al.</i> 2001 ¹⁴ LONFLIT 2	Duplex	1/411 (0.2%)	19/422 (4.5%)	Long haul flight passengers
8 Belcaro <i>et al.</i> 2002 ¹⁵ LONFLIT 4-1a	Duplex	0/179 (0%)	4/179 (2.2%)	Long haul flight passengers
9 Belcaro <i>et al.</i> 2002 ¹⁵ LONFLIT 4-1b	Duplex	0/136 (0%)	3/135 (2.2%)	Long haul flight passengers
10 Cesarone <i>et al.</i> 2003 ¹⁶ LONFLIT 4-2a	Duplex	0/97 (0%)	0/98 (0%)	Long haul flight passengers
11 Cesarone <i>et al.</i> 2003 ¹⁶ LONFLIT 4-2b	Duplex	0/75 (0%)	0/71 (0%)	Long haul flight passengers
12 Cesarone <i>et al.</i> 2003 ¹⁶ LONFLIT 4-3a	Duplex	0/72 (0%)	0/72 (0%)	Long haul flight passengers
13 Cesarone <i>et al.</i> 2003 ¹⁷ LONFLIT 4-3b	Duplex	0/64 (0%)	2/66 (3.0%)	Long haul flight passengers
14 Belcaro <i>et al.</i> 2003 ¹⁸ LONFLIT 5	Duplex	1/103 (1.0%)	6/102 (5.9%)	Long haul flight passengers

FUS: Fibrinogen uptake scan.

Duplex: Duplex ultrasonography.

reduction in patients assigned to knee length stockings was observed in the majority of trials, but for trials by Hui *et al.*¹¹ (THR) and Howard *et al.*,¹² risk increases were observed. The estimated odds ratio for a random effects model (adjusting for heterogeneity) was 0.35 (95% CI 0.13–0.97, $z = 2.03$, $p = 0.043$). When 0.5 was added to each cell frequency for trials in which no events were observed in one or other treatment arm, the odds ratio was 0.68 (95% CI 0.42–1.09, $z = 1.59$, $p = 0.11$) in the fixed effects model and 0.42 (95% CI 0.18–0.98, $z = 2.00$, $p = 0.046$) in the random effects model.

Finally meta-regression analysis was carried out to ascertain the effect of the type of subject on the overall

result. This effect was highly significant: the ratio of odds ratios for long haul subject trials was 0.14 (95% CI 0.04–0.57) in comparison with hospitalized subject trials. Thus knee length stockings were considerably more effective in long haul subjects than in hospitalized subjects.

Discussion

In 1858, Rudolph Virchow famously proposed that the alteration of one of the three characteristics of venous circulation (blood-flow, blood-composition and the attributes of the functioning vein) may precipitate

Table 3. DVT incidence in hospitalised patients: meta-analysis

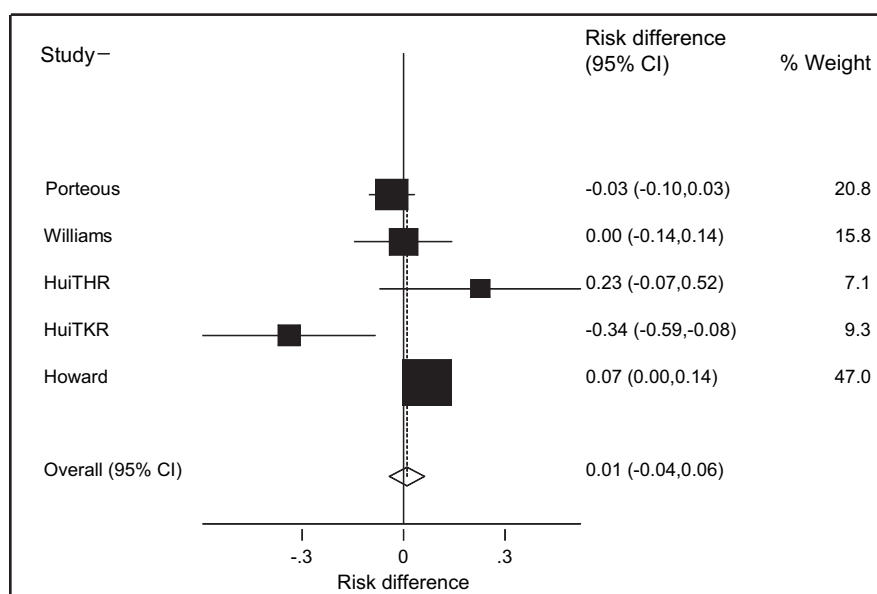
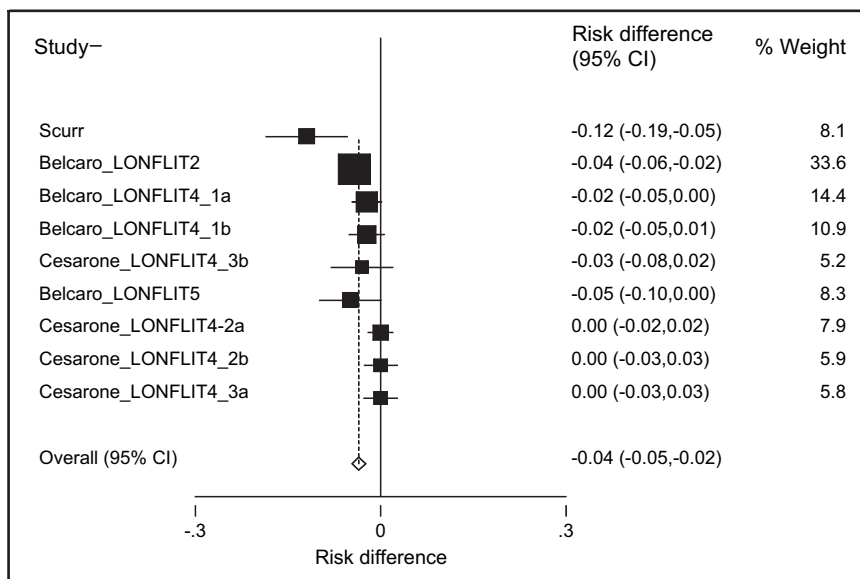


Table 4. DVT incidence for long haul flight passengers: meta-analysis

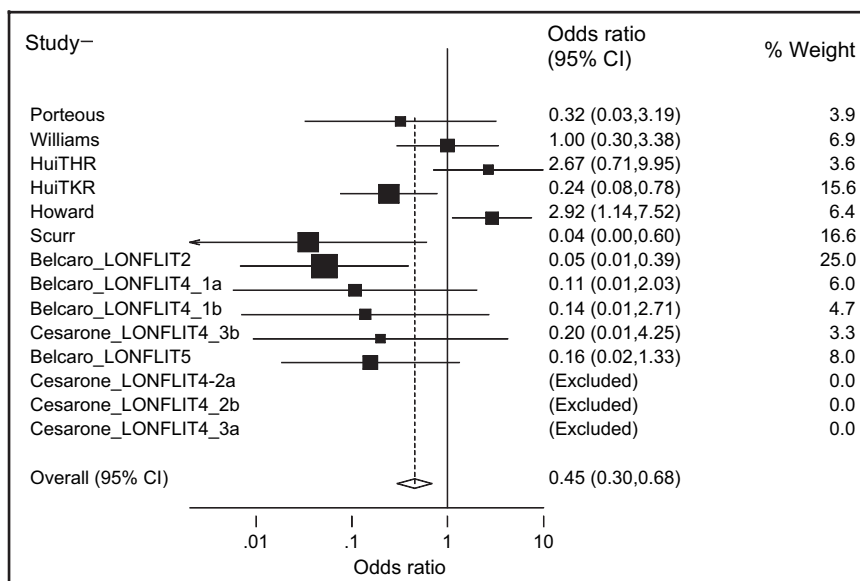


a thromboembolic event (Fig. 1). Endothelial injury (factor I of Virchow’s triad) can be induced by trauma, surgery, hypobaric or normobaric hypoxia and by indwelling catheters. Circulatory stasis (factor II) can be due to trauma, surgery, venous insufficiency or immobility. Hypercoagulability (factor III) can be due to malignancy, trauma, surgery, sepsis, protein C or S deficiency or nephrotic syndrome. Agu *et al.* have summarised the multifactorial mechanism of action of GCS in preventing DVT.¹⁹ By providing external mechanical support, GCS may increase venous blood

velocity,²⁰ decrease vein diameter,²¹ counteracting venous hypertension,²² controlling oedema,²³ restoring valve function²⁴ and relieving symptoms.²⁵ GCS therefore diminish one or more factors of Virchow’s triad: they decrease intimal tears, reduce stasis and decrease coagulability. Hence GCS are proven as a clinically important means of thromboprophylaxis, especially in postoperative patients.²⁶

Despite the early recognition of an association between travel and venous thromboembolism (Homans, 1954²⁷), it was not until recently that more informative

Table 5. DVT incidence in long haul flight passengers and hospitalised patients combined: meta-analysis



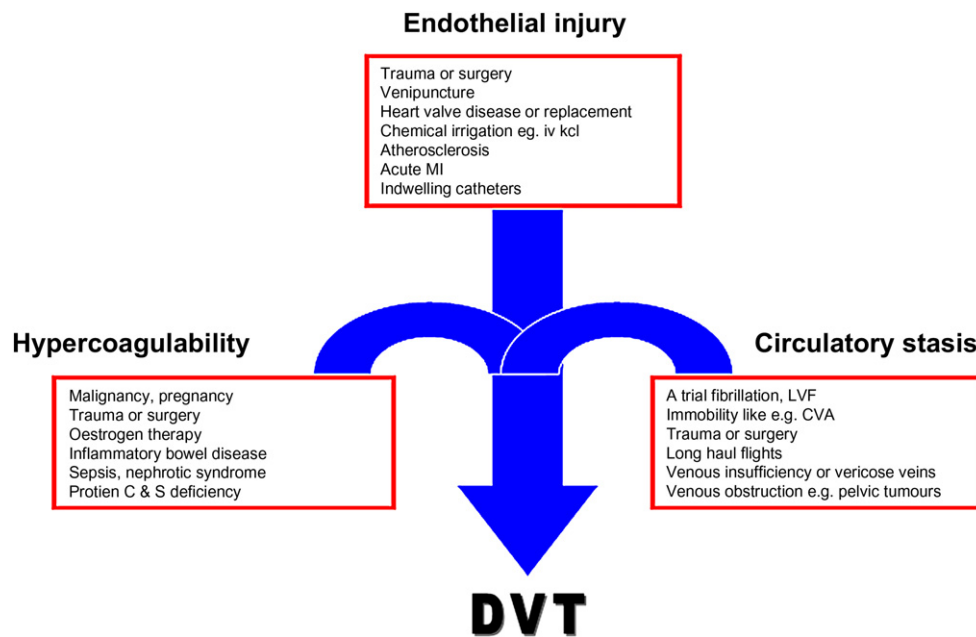


Fig. 1. Risk factors for DVT according to Virchow's triad.

studies have been performed. As the number of both air (estimated at 2 billion in 2005) and land passengers is predicted to rise, it is essential that advice given to inform travellers both of their thrombosis risk and of preventative strategies is evidence based. The LON-FLIT trials provide invaluable evidence of risk of DVT in this population. The risk factors shared by hospitalised and long haul flight population are presented in Table 6. Thrombosis risk is greater following journey of more than 8 hours and those at greatest risk are travellers with a history of venous thromboembolism. Based on the best evidence available the risk of symptomatic DVT after flights of more than 12 hours is 0.5%.²⁸ The risk of lower limb DVT in high risk subjects is 5% per flight and 1.6% per flight for lower risk subjects following long haul flights.²⁹ Regular DVT

prevention protocols for travel thrombosis are still controversial. Class I and Class II knee length graduated compression stockings with ankle pressure of 14–30 mm Hg. have shown reduction in lower limb DVT³⁰ in air travellers. Regular exercise plans for 5–10 min every hour, avoiding baggage between seats and drinking water regularly (100–150 ml per hour) for high risk population is recommended in few trials. Therefore, in both high risk and low risk passengers, knee length graduated compression stockings appear to be effective in reducing the risk of DVT.

The results of this review provide evidence that KL graduated compression stockings can produce a clinically significant risk reduction in the incidence of deep vein thrombosis in hospitalized subjects and subjects on long haul flights. The weighted odds ratio was 0.45 (95% CI 0.30–0.68, $p < 0.001$), indicating a 55% odds reduction. In high risk population incidence of DVT is 2.8%.¹⁸ In the control group there were 4.5% of subjects with DVT while in knee length stocking group DVT incidence was only 0.24%. The incidence of DVT observed when subjects were wearing stockings was 19 times lower than in controls. Knee length stockings were found to be beneficial in reducing incidence of DVT in this group.

There is a significant cost implication in the use of GCS in hospitals. We have shown that knee length and thigh length graduated elastic stockings can be equally effective in thromboprophylaxis. By using knee length elastic stocking many hospitals will save £5 per pair of graduated compression stockings and

Table 6. Common risk factors for DVT in hospitalised patients and long haul flight passengers

General Risk Factors

- Immobilisation (Illness, surgery, trauma, sitting in confined space for more than 8 hours).
- Dehydration (Blood and fluid loss, poor intake, dry environment, drinking).
- Cramped Conditions (Cubicles, narrow and crowded seats).
- Hypoxia (Low haematocrit, blood loss, respiratory disorders, normobaric or hypobaric hypoxia).

Specific Risk Factors

- Hypercoagulability of any origin.
- Age.
- Obesity
- Previous history of DVT/PE
- Malignant conditions.

a typical hospital of 250,000 patients might save the equivalent of more than £1.2 million per annum.

Our study has some limitations. One confounding variable was the use of other forms of thromboprophylaxis (e.g. LMWH) when the efficacy of graduated compression stockings were tested. For these reasons studies of long haul flight passengers have been useful, since such passengers usually have no additional pharmacological thromboprophylaxis. The total number of subjects in our study was relatively small, with a preponderance of studies on passengers on long haul flights. The merits of a summated analysis including hospital patients and long haul flight passengers is debatable, but is presented for interest given the overlapping risk factors for DVT in the two cohorts.

No large multicentre randomised control trial on hospitalized patients has been reported. This makes it difficult to conclude, on the basis of available evidence, that both KL and TL stockings are equally effective for thromboprophylaxis. This systematic review provides some evidence to suggest that knee length stockings can be used in hospital practice. Better clinical evidence (level 1) is needed in order to establish whether knee length graduated compression stockings for thromboprophylaxis are as effective as, or preferable to, thigh length stockings.

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Appendix for publication as web supplement: studies excluded from systematic review

Studies	Reason for exclusion
William AM <i>et al.</i> ⁴	DVT was not used as outcome of study.
Halford <i>et al.</i> ³¹	Length of stockings not mentioned.
Turner <i>et al.</i> ³²	Length of stockings not mentioned.
Allan <i>et al.</i> ³⁴	Length of stockings not mentioned.
McNally <i>et al.</i> ³³	DVT was not used as outcome of study.
Wells <i>et al.</i> ³⁴	Only two studies compared below knee stockings
Hatcher <i>et al.</i> ³⁵	Discussion paper.
Partsch <i>et al.</i> ³⁶	DVT was not used as outcome of study.
Inada K <i>et al.</i> ³⁷	Length of stockings not mentioned.
Hollingsworth <i>et al.</i> ³⁸	DVT was not used as outcome of study
Ingram JE ³⁹	Discussion paper
Benko <i>et al.</i> ⁴⁰	DVT was not used as outcome of study
Agu <i>et al.</i> ¹⁹	Only two studies on knee length stockings
Byrne B ⁷	Discussion paper
Hameed <i>et al.</i> ⁶	DVT was not used at outcome of study