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How can the pressure in anti-embolism stockings be maintained during use? Laboratory evaluation of simulated 'wear' and different reconditioning protocols

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ABSTRACT

Background: Deep vein thrombosis is a major global health issue, responsible for thousands of deaths each year. While thrombi can form under a variety of circumstances, lack of mobility significantly increases risk and therefore non-ambulant patients are frequently fitted with anti-embolism stockings on admission to hospital, to aid blood flow, prevent pooling and thus clotting. Anti-embolism stockings are the most widely used non-invasive medical device on the market and are believed to reduce the risk of deep vein thrombosis by 40%. Despite their widespread use in hospitals world-wide, there is remarkably little research addressing their use or reconditioning and a wide variety of different reconditioning protocols are used in hospitals.

Objective: The objective of this study was to establish the impact of different wear and reconditioning protocols on the pressure delivering ability of anti-embolism stockings.

Design/methods: A laboratory investigation was undertaken to evaluate the pressure delivering ability of 2 major global brands of anti-embolism stockings over 5-8 days of simulated wear (extension on static cylinders) and 4 different reconditioning protocols. 1 set of samples was continuously 'worn' for 8 days without reconditioning, 1 set of samples was 'worn' for 5 days with a day of relaxation between each day of 'wear', 1 set was 'hand washed' and 1 set was machine washed and then allowed to relax between each day of 'wear'. The pressure was measured at the beginning and end of each period of 'wear'.

Setting: This study was undertaken in a conditioned textile testing laboratory that complies with BS EN ISO 139:2005+A1:2011.

Results: The pressure exerted by anti-embolism stockings reduced by between 15 and 24% after 24 hours of wear, it reduced by between 21 and 32% when worn continuously for 8 days. Allowing stockings to rest for a day between days of wear allowed them to recover slightly but this recovery was only temporary. Washing stockings regenerated their pressure delivering potential significantly and machine washing allowed some to recover to exert more pressure than they had when new.

Conclusions: Different brands of anti-embolism stockings exert different pressures on the same size of leg, when correctly fitted. The pressure exerted by anti-embolism stockings decreases with use but the correct pressure gradient is maintained if correctly fitted. Washing stockings after 24 hours of wear is effective in restoring their pressure delivering abilities and in some cases can surpass their 'as new' pressure delivering ability.

What is already known about this topic?

- Anti-embolism stockings are used globally to prevent thrombosis development in many non-ambulant hospitalised patients.
- Anti-embolism stockings need to be fitted carefully to patients to ensure efficacy, compliance and a graduated pressure profile, ideally 18mmHg at ankle and 14mmHg at calf.
- Limited information on packaging of anti-embolism stockings, particularly the absence of ankle sizes, can make ensuring the correct pressure gradient impossible in a hospital setting.

What this paper adds

- The pressure exerted by anti-embolism stockings reduced over a period of 24 hours of wear, but the pressure gradient was maintained on appropriate ankle and calf circumferences.
- Using the same pair of stockings for more than a day leads to further pressure loss.
- Washing stockings, particularly machine washing at 60°C, regenerates their pressure delivering ability.

Keywords: Anti-embolism stockings

Deep vein thrombosis

reconditioning protocol

laundry

pressure

1. Introduction

The annual cost to the National Health Service of managing Deep Vein Thrombosis (DVT) in the UK surpasses £600million, due in part to the complicated long term care of DVT patients, therefore prophylaxis is paramount in reducing this potential spend (Dumbleton and Clift, 2008). It is suggested that 61% of the British public are at risk of DVT (Bergmann et al., 2010) and thousands of deaths each year are caused by pulmonary embolism, typically resulting from DVT, of which over 80% could have been prevented (Thomas et al., 2000).

Compression has been recognised for centuries as a medical aid to relieve symptoms of venous disorders (Aloi et al., 2009). Over the years its use has expanded to include prevention of DVT, which is known as a silent killer, hard to detect and linked to morbidity and long term suffering (Anderson et al., 2007, Aloi et al., 2008, Cohen et al., 2008, Geerts et al, 2008, Kyrle and Eichinger, 2005). Anti-embolism stockings are specifically designed for non-ambulant patients whilst in hospital settings (Dumbleton and Clift, 2008, Macintyre et al, 2013). The action of the anti-embolism stockings is to compress the deep venous system and compensate for the lack of contraction and expansion of the leg muscles and foot flex which is normal whilst ambulant. Anti-embolism stockings provide an increase in inter venous pressure to ensure blood flow back to the heart, preventing blood pooling and potential pulmonary embolism (Aloi et al., 2009, Dumbleton and Clift,2008, Lui et al., 2005, Macintyre et al., 2013, Maylor, 2001, Miyamoto et al., 2011, NPA, 2006). In the 1970s Dr Bernard Sigel established the industry "gold standard" for the compression profile of anti-embolism stockings (Autar, 2009): a graduated profile with 18mmHg at the ankle, 14mmHg at the calf, 8mmHg at the popliteal, 10mmHg at the lower thigh and 8mmHg at the upper thigh (Aloi et al., 2009, Autar, 2009, Carolon, 2009, Dumbleron and Clift, 2008, Huntleigh, 2012, Knott, 2010, Maclellan, 2002, Patel, 2016, Saphena, 2010, Sigel et al., 1975) and this remains the target for

manufacturers today. The Laplace Law is used by manufacturers to predict the pressure exerted by their compression hosiery (AFNOR, 1986, BSI, 1985, 1993, 1999, CEN, 2001a, 2001b, RAL, 2008, Thomas, 1993).

Anti-embolism stockings are the most widely used, non-invasive medical device on the market. The use of anti-embolism stockings alone is said to reduce DVT by 40% and in conjunction with pharmacological methods up to 85% reductions can be achieved (Autar, 2009, Byrne, 2001, Dumbleton and Clift, 2008, Gandi et al., 1984, Miller, 2011). The use of mechanical prophylaxis in England, Wales and Northern Ireland was increasing each year (National Joint Registry, 2014) for numerous reasons, namely: cost, ease of use and minimising complications. The global compression market continues to grow and was suggested to be worth $2billion in 2011 (ASDR, 2012). Recently the CLOTs trial (Bath and England, 2009) showed that anti-embolism stockings provided no beneficial reduction in DVT among stroke patients. However, the trial protocol did not require patient's legs to be measured before stockings were fitted. Therefore, the pressures and pressure gradients are not known and will not have been consistently applied to all patients in the trial. Previous work showed that in a sample of 942 legs between 0 and 87% of thigh length and 62 and 100 % of knee length anti-embolism stockings could be 'correctly' fitted by 4 major brands of anti-embolism stockings (Macintyre et al., 2013). Further the brand achieving 100% fit in below knee anti-embolism stockings only provided one measurement point, so it would be impossible for staff to ensure the correct pressure gradient on the patient's leg. Therefore, it is likely that different pressure gradients were applied to the legs of patients in the CLOTs trial, which one would expect to lead to different levels of treatment success.

There is limited published data on the effects of anti-embolism stockings aftercare or the degradation in the pressure exerted over time. The guidelines by manufacturers range from recommending a 40° hand wash (Urgo Medical, 2013) to a 75° machine wash (G&N Medical, 2013). Previous work on related products (Macintyre et al., 2007) showed that pressure exerted by garments decreased over the wear period but that washing could regenerate the garment's pressure exerting potential. Further the type of washing affected the extent of the garment's regeneration.

Anti-embolism stockings are the recommended prophylaxis for DVT prevention in a wide group of non-ambulant patients. Anecdotal evidence suggests that there are different protocols for their use in different hospitals with some patients wearing a single pair of anti-embolism stockings for their entire stay in hospital, while others have their stockings removed for laundry daily to be replaced with a second pair. This study aimed to evaluate the impact of 4 sets of different 'wear' and reconditioning protocols on the pressures exerted by 2 commonly used brands of anti-embolism stockings.

2. Methods

2.1. Samples

Test specimens were prepared from the ankle and calf portions of 2 major anti-embolism stocking brands (X and Y). All stockings were size medium. Tubular specimens were prepared by cutting 50mm sections from the ankle (A) and calf (C) portions of each anti-embolism stocking. Extreme care was taken to ensure that specimens were cut following a single course of knitting and no elastane yarns were damaged during the sample cutting process. Twenty replicate test specimens

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were cut at both ankle and calf of both brands of anti-embolism stockings. These were sorted into 4 sets of specimens, each set consisting of 5 replicate ankle and calf specimens from brand X and brand Y. All sample codes consisted of a prefix indicating the 'wear' and reconditioning protocol followed by X or Y for the brand and A or C for the portion of stocking tested.

2.2. Wear and reconditioning protocols

The four different sets of specimens were tested according to four different test protocols. In each case the simulated 'wear' consisted of specimens being stretched on static rigid polythene cylinders of either ankle (21.6cm) or calf (34.8cm) circumference for 24 hours. The 4 testing protocols were:

1. Continuous 'wear' = specimens were placed on the cylinders for 8 consecutive periods of 24 hours, less 3 minutes for testing on an Instron tensile tester. All sample codes are prefixed 'CE'.
2. 'Wear' and dry relax = specimens were placed on the cylinders for 24 hours, removed for 24 hours and left to relax, this was repeated a total of 5 times (5 days 'wear' plus 5 days resting). All sample codes are prefixed 'DR'.
3. 'Wear' and 'hand' wash @ 40°C = specimens were placed on the cylinders for 24 hours, removed for washing/drying/conditioning and then re-placed on cylinders 24 hours later for a total of 5 days of 'wear'. Specimens were washed in a British Standards Institute (BSI) washcator machine using the BSI 7A simulated hand wash cycle, i.e. 70 minute cycle at 40°C with 'gentle' agitation. All specimens were placed in a small net bag to prevent unravelling and the wash load was made up to 500g using cotton make-weights. 20g of Persil automatic washing detergent was used. All sample codes are prefixed '40'.
4. 'Wear' and machine wash @ 60°C = as described at 3 above except that BSI 12 machine wash cycle was used , i.e. 74 minutes at 60°C with 'normal' agitation. All sample codes are prefixed '60'.

2.3. Tension testing and pressure calculation

The first time each specimen was tested it was placed on an Instron 3345 tensile testing machine (standard laboratory equipment for measuring load/elongation properties of textiles), fitted with loop specimen holders, and extended at a rate of 60mm/min. The looped gauge length was 120mm for ankle specimens and 160mm for calf specimens and the maximum looped extension was 216mm for ankle specimens and 348mm for calf specimens, i.e. they were extended to the same 'circumference' as the cylinder they would be extended on during the simulated 'wear'.

Immediately after each specimen was tested on the Instron it was removed and placed on its cylinder, ensuring that the specimen was straight and even. After 24 hours ±1 minute of extension each specimen was removed from its cylinder and fabric tension was re-measured. Cylinder circumferences were within the range of 'medium' calf and ankle girths recommended on the size charts of the 2 brands of anti-embolism stockings tested.

The loads in Newtons per sample, measured on the Instron tensile testing machine, were converted to Nm^{-1} and then the equivalent pressure in mmHg was calculated using the Laplace Law and the appropriate cylinder circumference.

2.4. Statistical analysis

The 95% confidence intervals of each set of data were calculated so that it could be determined whether results were statistically different to one another or not. In the discussion of results the word 'similar' will be used to indicate when results were not statistically significantly different to one another. The Pearson's correlation coefficient was also calculated, using Minitab 17, for sets of data to identify underlying relationships.

3. Results

3.1. Continuous extension

Table 1 shows that the pressure exerted by all samples of anti-embolism stocking reduced with continuous extension over time. This reduction in pressure was most dramatic in the first 24 hour period, with all sample groups exerting significantly lower pressures, at 95% confidence level, after 24 hours of extension. The measured tension and calculated pressure continued to drop throughout the extension period but these reductions in pressure were often not statistically significant from one 24 hour extension to the next.

Table 1 also shows that the 2 different brands of stockings exerted different pressure profiles compared to one another. Brand Y exerted significantly higher pressures at both ankle and calf (at all times) than brand X. Table 1 shows that although each set of samples lost a different amount of their initial pressure there was no correlation between the initial pressure and the amount lost over time.

3.2. Dry relaxation - anti-embolism stockings relaxed, without washing, between use

Table 2 showed that all samples, of both brands and measurement locations, prefixed 'DR' recovered some of their pressure delivering potential when they were removed from the cylinder and allowed to relax for 24 hours. However, when pressures before each extension and after 24 hours of rest were correlated with the hours of extension there was a significant negative correlation at the 95% confidence level (DR-XA r = -0.865; DR-XC r = -0.89; DR-YA r = -0.812; DR-YC r = -0.881). Each set of 'DR' samples exerted significantly less pressure at the start of the 2nd or 3rd period of 'wear' than their first. Similarly the pressures exerted by all 'DR' samples after each 24 hour extension correlated negatively (DR-XA r = -0.905; DR-XC r = -0.954; DR-YA r = -0.937; DR-YC r = -0.885) with hours extended. However, this difference between pressure at the end of the first and subsequent periods of extension was not always statistically significant: neither DR-XA or DR-XC samples had significantly lower pressures at the end of the 5th extension period than the 1st; while DR-YA samples exerted significantly less pressure at the end of the 3rd extension period than they had at the end of the 1st; and DR-YC exerted significantly less pressure at the end of their 2nd period of extension than they had at the end of the 1st.

3.3. 40°C simulated hand wash

Table 3 shows the initial pressure and the pressure exerted by each sample after each period of extension and handwashing/recovery. All sample sets that were given a British Standard simulated hand wash following each period of 24 hour extension delivered (statistically) similar pressures at the start of each period of extension. However, it was noted that sample set 40-XC showed a correlation (at 99% confidence; r = -0.938) between increased extension time and decreased

pressure at the beginning of each extension, no such correlation was observed in the other samples. There was no statistically significant difference between the pressures exerted at the end of each wear period when samples were hand washed between periods of extension. Nor was there any correlation between the number of 'wear'/reconditioning cycles and the pressure exerted.

3.4. 60°C machine wash

Table 4 shows the pressure before and after each period of extension and machine washing/ recovery. More detailed analysis of the results shows that there was no significant difference between the pressures exerted by brand X samples at the start of each period of extension nor any strong correlation between pressures exerted and number of extension periods (60-XA r = -0.816 is significant at 95% confidence but 60-XC r = -0.131). However, brand Y anti-embolism stockings samples showed a strong positive correlation (60-YA r = 0.959; 60-YC r = 0.931; both of which are significant at 99% confidence) between the pressures exerted at the beginning of each period of wear, after 60°C machine wash and recovery, and the number of wear/wash cycles. This trend was backed up by statistically significant increases in pressure exerted after reconditioning and at the start of wear cycles 4 and 6 for 60-YA samples and at the start of wear cycles 5 and 6 for 60-YC samples.

For any given sample, the pressure exerted at the end of each period of wear was not significantly different from the pressure it exerted at the end of the first period of wear and there were no significant correlations between the number of wear/wash extensions and pressure exerted.

3.5. Comparison of 3 wear/reconditioning protocols with continuous extension

Figure 1 shows an example of the anti-embolism stockings' response to the different methods of sample reconditioning, which will be referred to as 'interventions'. The troughs in each intervention plot show the pressures recorded at the end of each 24 hour period of extension, or simulated wear. The peaks in each intervention plot show the initial pressure and recovered pressures following reconditioning, these are the same as the pressures at the start of the next 'wear'. Three different sets of intervention conditions are shown at the beginning and end of 5 periods of 24 hours extension; these are plotted with calf samples of stocking Y that were extended continuously for 8 periods of 24 hour extension. Note that the intervention samples rested for 48 hours between extension 3 and 4.

Figure 1 shows the pressures exerted by samples of Brand Y stockings on an appropriate calf circumference. All YC samples exerted similar pressures at the start of the study. All sample sets exerted significantly lower pressures at the end of their first period of extension than they had at the beginning. All the interventions caused a significant recovery of pressure delivering ability during rest or wash/dry/rest between each period of extension.

Washing the samples delivered a significant improvement in the pressure recovered compared to no recovery or allowing samples to recover by simple dry relaxing. Further, machine washing samples at 60°C resulted in marginally higher pressures being exerted compared to reconditioning using the simulated hand wash at 40°C in all calf (and ankle samples) after the second extension, and many of the increases in pressure were statistically significant. The washed intervention samples exerted similar pressures at the end of 5 periods of 24 hour extension to those after 1 period of 24 hour

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extension. There was no significant correlation between the number of 'wear/wash' cycles and the pressure exerted.

The 'dry relax' samples recovered during periods of rest to deliver significantly higher pressures at the beginning of each extension period than they were exerting at the end of the previous extension. However, by the end of each extension period they were exerting similar pressures to the continuously extended anti-embolism stockings samples.

4. Discussion

According to Sigel (Sigel et al., 1975) the 'ideal' pressure profile for anti-embolism stockings would be 18mmHg at the ankle and 14mmHg at the calf. However, the British Standard for anti-embolism stockings recommends ankle pressures between 10 and 18mmHg while calf pressures should not exceed 80% of ankle pressure and be between 8 and 14mmHg (BSI, 1993). Brand Y initially exerted more pressure than Sigel's ideals at both measurement points on our test circumferences. However, by the end of the experiment brand Y exerted an average 18.4mmHg to the ankle and 11.8mmHg to the calf. Brand X exerted lower than Sigel's ideal pressures throughout the study. However, the pressure gradient at our test circumferences was broadly acceptable, i.e. higher pressure exerted at ankle than calf, in all samples at all times during this investigation.

The pressure exerted by anti-embolism stockings drops significantly over a 24 hour period of wear/extension. The pressure continued to drop, albeit at a slower rate, if anti-embolism stockings were left on the 'leg' for a period of several days. Although the general trend was consistent between brands and measurement locations, the magnitude and significance of the reduction in pressure varied between brands and measurement locations. Removing stockings and allowing them to relax for 24 hours (dry relaxation) offered a slight benefit in terms of regenerating their pressure delivering potential. However, none recovered fully and all lost a little more of their pressure delivering potential with each period of use/recovery. Thus, while there is some benefit to issuing 2 pairs of anti-embolism stockings to each patient and wearing these stockings on alternate days, the pressure exerted by these stockings will be reduced each day if they are not washed between days of wear. Therefore, the benefit of recovery time between wearing periods was small and temporary and thus of little practical use, especially given the increased cost associated with issuing each patient with 2 pairs of stockings.

Washing stockings after 24 hours of 'wear' regenerated their pressure delivering ability more effectively than dry relaxation. Gentle or 'hand' washing at 40°C resulted in the pressure delivering ability of stockings being restored to similar levels to those of new stockings. Therefore, hand washing was effective at stabilising the pressures exerted by these 2 brands of anti-embolism stockings for up to 5 days of wear. Machine washing stockings at 60°C restored one brand to 'as new' pressure delivering ability and enabled the other brand of stockings to exert higher pressures after wear and wash than they did when new. This marginal increase in pressure could compensate slightly for pressure lost during wear. Thus washing anti-embolism stockings between periods of wear (at least daily) should be recommended.

Although the pressure declined during wear in all stockings the pressure gradient was maintained at all times when tested on appropriate ankle and calf circumferences and would thus be providing some benefit to the patients. Anti-embolism stockings that exerted pressures at the higher end of

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the acceptable range would continue to exert acceptable, albeit lower, pressures throughout use for at least 5 washes. Thus, well fitted and regularly laundered anti-embolism stockings provide a cheap and convenient way to encourage venous return and reduce the risk of DVT.

5. Limitations

Note that pressure is determined by the inherent tension in the stocking (as determined by its construction and raw materials) and the circumference of the cylinder or body part onto which it is placed, as well as the impact of 'wear' and reconditioning measured here. Thus the pressures discussed in this study are indicative and would change if different products were used or the same product was placed on a different circumference of cylinder or leg. However, the underlying trends in response to extension, or being worn, and reconditioning would be relatively consistent regardless of leg size.

It is also acknowledged that this is a laboratory simulation of anti-embolism stocking wear, rather than a wearer trial. Sections of stockings were tested, rather than whole stockings and while this is standard laboratory practice it may have influenced results. Wear was simulated on static cylinders with no movement and no human factors such as sweat, skin oils and skin shedding were assessed. Despite these limitations we believe that the findings can usefully be extrapolated to inform practice.

6. Conclusions

This is the first study to evaluate the impact of different reconditioning protocols on the pressures exerted by anti-embolism stockings. It showed that anti-embolism stockings loose pressure during use but that the pressure gradient is maintained when fitted on appropriate ankle and calf circumferences. The pressure exerted by anti-embolism stockings can be regenerated to 'as new' levels by machine or hand washing.

References

AFNOR-NFG-30-102b, 1986. Determination de la pression de contention. Articles de bonneterie.

Aloi, T., Astara, Ca., et al, 2009. Compression Consensus document based on scientific evidence and clinical experiences. Edizioni minerva medica, Torino.

Anderson, F., Zayaruzny, M., et al, 2007. Estimated annual numbers of US acute-care hospital patients at risk for venous thromboembolism. American Journal of Hematology. 777-782.

ASDR Report: The Global Compression Therapy Market is Forecast to Exceed $2.5 Billion in 2018, 2012. https://www.asdreports.com/market-research-report-277606/compression-therapy-market-global-industry-analysis-size-share-growth-trends, (accessed 27.04.15)

Autar, R., 2009. A review of the evidence for the efficacy of Anti-embolism Stockings (AES) in Venous Thromboembolism (VTE) prevention. Journal of Orthopaedic Nursing. 13, 41-49.

Bath, P., England, T., 2009. Thigh Length Compression stockings and DVT after stroke. The Lancet. 373, 1923-1924

Bergmann, J., Cohen, A., et al., 2010. Venous thromboemobolism risk and prophylaxis in hospitalised medically ill patients. Thrombosis and Haemostasis, 103, 4, 736-748.

BSI, 1985. British Standards Institute. BS 6612:1985 British Standard Specification for Graduated compression hosiery.

BSI, 1993. British Standards Institute. BS 7672:1993 British Standards Specification for Compression, stiffness and labelling of anti-embolism hosiery.

BSI, 1999. British Standards Institute. BS 7563:1999 Non-prescriptive graduated support hosiery.

Byrne, B. 2002. Deep Vein Thrombosis Prophylaxis: The Effectiveness and implications of using below knee or thigh-length graduated compression stockings. Journal of Vascular Nursing, 20, 2, 53-59.

CEN, 2001a. Medical compression hosiery DD ENV12718 (Draft for development). Edited by BSI. London.

CEN, 2001b. Medical thrombosis prophylaxis hosiery DD ENV12719: 2001. Edited by BSI. London.

Carolon Graduated Compression, 2009. Summary of Test Results V's Sigel Profile. http://www.hrhealthcare.co.uk/downloads/carolon/Test-Results-vs-Siegel-Profile.pdf (accessed 10.05.16)

Cohen, A., Tapson, V., et al, 2008. Venous thromboembolism risk and prophylaxis in the acute hospital care setting (ENDORSE study); a multinational cross-sectional study. The Lancet. 387-394.

Dumbleton, T., Clift, M., 2008. Buyers Guide: Compression Hosiery. CEP08036. NHS Purchasing and Supply Agency. 1-73.

Gandi, D., Lewis, B., et al, 1984. Clinical comparison of elastic supports for venous diseases of the lower limb. Postgraduate Medical Journal. 60, 349-352.

Geerts, W., Bergqvist, D., et al, 2008. Prevention of Venous Thromboembolism: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines (8th Edition). Chest. http://chestjournal.chestpubs.org/content/133/6_suppl/381S.full.html (accessed 08.03.12)

G&N Medical, Saphena Medical Below Knee Anti-Embolism Stockings Packaging with Stockings, Product Reference Standard 23-26cm (purchased 2013).

Huntleigh, A. 2010. Preventing Venous Thromboembolism with Flowtron DVT prophylaxis Systems. http://www.arjohuntleigh.com/Page.asp?PageNumber=3980 (accessed 14.03.13).

Knott, L. 2010. Prevention of Deep Vein Thrombosis. http://patient.info/doctor/deep-vein-thrombosis-pro, (accessed 11.05.10).

Kyrle, P., Eichinger, S., 2005. Deep Vein Thrombosis. The Lancet, 365, 1163-1174.

Lui, R., Kwok, Yi et al, 2005. Objective Evaluation of Skin Pressure Distribution of Graduated Elastic Compression Stockings. Dermatologic Surgery. 31, 615-624.

Macintyre, L., Gilmartin, S., Rae, M, 2007. The Impact of Design Variables and Aftercare Regime on the Long-Term Performance of Pressure Garments. Journal Burn Care & Research 28 ,5, 1-9.

Macintyre, L., Kent, K., McPhee, D., 2013. Do anti-embolism stockings fit our legs? Leg survey and data analysis. International Journal of nursing Studies. 50, 914-923.

MacLellan, DG., 2002. Compression Profiles of Antiembolic Stockings. Australian and New Zealand Journal of Phlebology. 6, 1, 9-14.

Maylor, M., 2001. Accurate selection of compression and antiembolic hosiery. British Journal of Nursing. Oct 11-24, 10, 1172-1184.

Miller, J. 2011. Use and wear of Anti-embolism stockings: a clinical audit of surgical patients. International wound journal. 8, 1, 74-83.

Miyamoto, N., Hirata, K., et al., 2011. Effect of pressure intensity of graduated elastic compression stocking on muscle fatigue following calf-raise exercise. Journal of Electromyography and Kinesiology. 21, 249-254.

National Joint Registry for England, Wales and Northern Ireland. 2014. 11th Annual Report http://www.njrcentre.org.uk/njrcentre/Portals/0/Documents/England/Reports/11th_annual_report/NJR%2011th%20Annual%20Report%202014.pdf (accessed 27.04.15)

NPA Drug Tariff Handbook, 2006. 4, 96-112.

Patel, K. 2016. Deep Vein Thrombosis. http://emedicine.medscape.com/article/1911303-overview (accessed 24.03.16)

RAL, 2008. Deutsches Institut Fur Gutesicherung Und Kennzeichnung E.V..RAl-GZ 387/1. Medical Compression Hosiery. Sankt Augustin

Saphena Medical, 2010. G+ N Medical Ward Pack.

Sigel, B., Edelstein, A., et al. 1975. Type of Compression for Reducing Venous Stasis. A Study of Lower Extremities During Inactive Recumbency. Archive of Surgery. 110, 2, 171-175.

Thomas, S. 1993. Determining the pressure and stiffness of anti-embolism stockings. Test Method 71. Surgical Materials Testing Laboratory. 1-19.

Thomas, S., Toyick, N., Fisher, B, 2000. Graduated External Compression and the Prevention of Deep Vein Thrombosis. Surgical Materials Testing Laboratory, Bridgend. SMTL.

Urgo Medical, Preventex Anti-embolism Stockings Packaging with stockings Product code 223, NPC Code EGD7433 (supplied 2013).
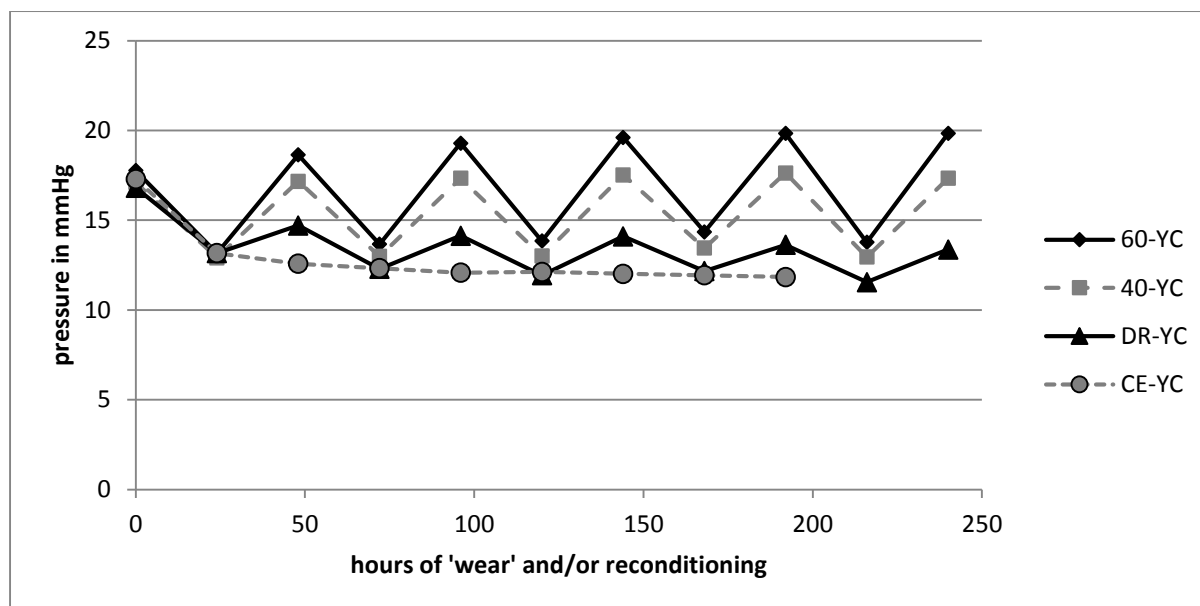
Figure 1 – impact of different 'wear' and reconditioning protocols on the pressure exerted by samples of the calf portion of brand Y stockings. Sample codes are prefixed CE for continuous extension, DR for samples relaxed for 24 hours between 'wears', 40 when 'hand' washed at 40°C then dried for 24 hours, and 60 when machine washed at 60°C then dried for 24 hours; the Y represents brand Y and the C tells us the samples were taken from the calf portion of the stocking.

Table 1 – Mean pressures (and 95% confidence intervals) exerted by anti-embolism stocking samples during continuous extension on cylinder. Sample codes are comprised of CE- for Continuous Extension, X or Y representing the stocking brand and A or C indicating either Ankle or Calf samples.

pressure in mmHg exerted on cylinder after:	CE-XA			CE-XC			CE-YA			CE-YC		
	LCI	Mean	UCI	LCI	Mean	UCI	LCI	Mean	UCI	LCI	Mean	UCI
0 'wear' (1 minute)	16.0	16.3	16.7	12.0	12.1	12.2	24.8	25.0	25.3	16.8	17.1	17.4
1 'wear' (24 hours)	13.5	13.8	14.0	9.4	9.5	9.5	20.2	20.4	20.5	12.7	13.0	13.4
2 'wear' (48 hours)	13.5	13.8	14.1	8.9	9.1	9.3	19.3	19.6	19.9	12.3	12.5	12.7
3 'wear' (72 hours)	13.1	13.3	13.5	8.9	9.0	9.1	19.1	19.2	19.4	11.9	12.2	12.6
4 'wear' (96 hours)	13.0	13.2	13.4	8.7	8.8	8.9	18.6	18.9	19.1	11.7	12.0	12.2
7 'wear' (168 hours)	12.7	12.8	13.0	8.6	8.7	8.8	18.6	18.7	18.8	11.5	11.8	12.1
8 'wear' (192 hours)	12.5	12.8	13.0	8.5	8.6	8.7	18.2	18.4	18.6	11.5	11.7	12.0

Table 2 – Mean pressures (and 95% confidence intervals) exerted by anti-embolism stocking samples after periods of extension on cylinder and reconditioning, consisting of 24 hour periods of relaxation. Sample codes are comprised of DR- for Dry Relaxation, X or Y representing the stocking brand and A or C indicating either Ankle or Calf samples.

pressure in mmHg exerted on cylinder after:	DR-XA			DR-XC			DR-YA			DR-YC		
	LCI	Mean	UCI	LCI	Mean	UCI	LCI	Mean	UCI	LCI	Mean	UCI
0 'wear' (1 minute)	15.4	16.1	16.8	11.9	12.4	12.9	23.6	24.2	24.7	16.2	16.8	17.4
1 'wear' (24 hours)	12.4	12.8	13.2	9.0	9.2	9.4	18.9	19.3	19.7	12.8	13.2	13.5
1 wear and recondition	14.5	15.2	15.9	10.8	11.2	11.5	21.3	21.7	22.2	14.3	14.7	15.1
2 'wear' (48 hours)	12.0	12.6	13.1	8.7	9.1	9.4	18.1	18.5	19.0	11.9	12.3	12.7
2 wear and recondition	14.1	14.7	15.3	10.6	11.0	11.4	20.8	21.3	21.8	13.7	14.1	14.6
3 'wear' (72 hours)	11.8	12.4	13.0	8.6	8.9	9.2	17.9	18.2	18.6	11.5	11.9	12.4
3 wear and recondition	14.1	14.8	15.4	10.7	11.0	11.4	21.1	21.4	21.8	13.7	14.1	14.5
4 'wear' (96 hours)	11.7	12.5	13.3	8.6	8.9	9.2	17.9	18.3	18.6	11.6	12.2	12.7
4 wear and recondition	13.8	14.4	15.1	10.2	10.6	11.0	20.1	20.5	21.0	13.1	13.6	14.1
5 'wear' (120 hours)	11.5	12.0	12.5	8.4	8.7	9.0	17.3	17.8	18.2	11.1	11.6	12.0
5 wear and recondition	13.8	14.5	15.2	10.0	10.4	10.8	20.5	20.9	21.3	12.9	13.4	13.9

Table 3 – Mean pressures (and 95% confidence intervals) exerted by anti-embolism stocking samples after periods of extension on cylinder and reconditioning by simulated hand washing at 40°C. Sample codes are comprised of 40- for 40°C 'hand' wash, X or Y representing the stocking brand and A or C indicating either Ankle or Calf samples.

pressure in mmHg exerted on cylinder after:	40-XA			40-XC			40-YA			40-YC		
	LCI	Mean	UCI	LCI	Mean	UCI	LCI	Mean	UCI	LCI	Mean	UCI
0 'wear' (1 minute)	15.7	16.2	16.6	11.6	12.2	12.7	24.3	24.8	25.3	16.5	17.1	17.7
1 'wear' (24 hours)	12.9	13.2	13.6	9.0	9.3	9.6	19.5	19.8	20.1	12.1	12.3	12.5
1 wear and recondition	15.6	15.9	16.3	11.3	11.8	12.2	24.3	24.6	24.9	16.6	17.2	17.8
2 'wear' (48 hours)	12.4	12.8	13.2	8.6	8.9	9.3	19.0	19.4	19.8	12.6	13.0	13.4
2 wear and recondition	15.2	15.7	16.1	11.1	11.6	12.1	23.8	24.2	24.6	16.8	17.3	17.9
3 'wear' (72 hours)	12.4	12.8	13.2	8.4	8.8	9.1	19.2	19.5	19.9	12.7	13.0	13.3
3 wear and recondition	15.6	16.1	16.5	11.2	11.6	12.0	24.2	24.6	25.0	17.0	17.5	18.1
4 'wear' (96 hours)	12.8	13.1	13.4	8.6	9.0	9.4	19.4	19.9	20.4	13.0	13.5	13.9
4 wear and recondition	15.1	15.6	16.0	11.0	11.4	11.9	24.1	24.4	24.8	17.0	17.6	18.2
5 'wear' (120 hours)	12.3	12.6	13.0	8.4	8.7	9.0	18.9	19.2	19.6	12.4	13.0	13.5
5 wear and recondition	15.4	15.8	16.3	10.8	11.3	11.7	24.3	24.7	25.1	16.9	17.3	17.8

Table 4 – Mean pressures (and 95% confidence intervals) exerted by anti-embolism stocking samples after periods of extension on cylinder and reconditioning by machine washing at 60°C. Sample codes are comprised of 60- for 60°C machine wash, X or Y representing the stocking brand and A or C indicating either Ankle or Calf samples.

pressure in mmHg exerted on cylinder after:	60-XA			60-XC			60-YA			60-YC		
	LCI	Mean	UCI	LCI	Mean	UCI	LCI	Mean	UCI	LCI	Mean	UCI
0 'wear' (1 minute)	15.5	16.1	16.6	12.1	12.4	12.7	24.3	24.9	25.5	17.3	17.8	18.2
1 'wear' (24 hours)	12.7	13.1	13.5	9.1	9.3	9.5	19.4	19.8	20.2	12.8	13.2	13.5
1 wear and recondition	15.9	16.5	17.1	12.1	12.4	12.6	24.7	25.2	25.8	18.1	18.6	19.2
2 'wear' (48 hours)	12.1	12.6	13.1	8.9	9.0	9.2	19.3	19.7	20.2	13.4	13.7	13.9
2 wear and recondition	15.7	16.3	16.9	12.1	12.3	12.6	25.2	25.8	26.4	18.7	19.3	19.9
3 'wear' (72 hours)	12.2	12.6	13.0	8.8	9.0	9.1	19.4	19.9	20.4	13.4	13.8	14.3
3 wear and recondition	16.2	16.8	17.4	12.3	12.6	12.9	25.9	26.5	27.1	19.1	19.6	20.1
4 'wear' (96 hours)	12.6	13.0	13.4	9.1	9.2	9.4	19.8	20.3	20.8	14.0	14.4	14.7
4 wear and recondition	15.9	16.6	17.2	12.2	12.4	12.7	25.6	26.2	26.9	19.3	19.8	20.4
5 'wear' (120 hours)	12.3	12.8	13.3	8.9	9.0	9.2	19.3	19.8	20.4	13.4	13.8	14.1
5 wear and recondition	16.1	16.8	17.4	12.1	12.3	12.5	26.2	26.9	27.7	19.3	19.8	20.4