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Blast Performance of Commercially Available Demining Footwear

A Summary of Experimental Trials with Frangible Surrogate Lower Legs

J.M.L. Mah, M.P. Braid and R.W. Fall
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Technical Memorandum
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Abstract

Eight commercially available demining boots were tested for their ability to provide protection against the effects of surrogate anti-personnel blast mines. Boot performance was determined based on post-blast evaluation by a trauma surgeon of frangible surrogate lower legs (FSLLs). None of the conventional demining boots tested provided significant protection.

Résumé

Huit bottes de déminage disponible sur le marché ont été testées contre des substituts de mine terrestre anti-personnelle (AP) à effets de souffle. Les performances protectrices des bottes ont été déterminées selon l'evaluation post-essai d'un chirurgien traumatologue des modèles de la jambe inférieure cassable (MJIC). Aucune des bottes traditionelles testées n'a procuré une protection significative.

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Executive summary

The blast protective capabilities of eight commercially available demining boots were tested against surrogate anti-personnel (AP) blast mines. Two types of boots were investigated: conventional demining boots (including those manufactured by Wellco® Enterprises Inc., DIS Design / Anonymate, Zeman Shoe Ltd., Force Ware GmbH, and Aigis Engineering Solutions Ltd.); and platform style boots (including those manufactured by Fevam America Inc, the Samad Rubber Works Ltd., and Med-Eng Systems Inc.).

The technique used to test all boots was adopted from the NATO methodology for testing personal protective equipment (PPE), and used frangible surrogate lower limbs (FSLLs) to evaluate leg injuries. An experienced trauma surgeon, blinded to the protective equipment and charge size used, documented all of the injuries for each FSLL, summed the total of the injuries, and assigned a Mine Trauma Score (MTS).

In every test using a conventional demining boot against a 50g charge (about the size of a VS50 mine) or a 75g charge (slightly less than the size of a PMA-2 mine), amputation would have resulted--the Force Ware boot being the only exception. A single test using the Force Ware boot against a 50g charge indicated that a salvageable limb might result. However, all tests against a much smaller charge (25g) resulted in amputations suggesting that either the 50g test was an anomaly or the response of the boot to the larger charge unexpectedly caused less damage to the leg. Clearly, more investigation is required. The three Aigis, Wellco, and Anonymate boots tested against 25g surrogate AP mines would have resulted in salvageable limbs but surgery would be required. Two of the three Zeman boots tested would have likely resulted in salvageable limbs, but one would have required an amputation. The American Combat boot would have required amputations for all trials performed with them.

The Fevam platform and Samad Rubber Works boots were tested in limited numbers. Two tests were conducted with the Fevam platform – the test conducted with a 75g charge resulted in a salvageable limb, but the test conducted with a 50g charge did not. This may indicate that this boot also requires further investigation. In the two tests conducted with the Samad Rubber Works boot – both the 25g and 50g tests resulted in FSLLs requiring amputations. The Med-Eng Systems Inc. boot, also known as the Spider Boot, was not tested in this series. The United States Department of Defence has previously conducted thorough tests on this boot. From those trials, the Med-Eng boot is known to be effective against up to 200 grams of C4.

Although a boot may perform well against the blast effects, there are other problems associated with them - excessive weight and decreased mobility, in particular. Other factors such as terrain, comfort, and cultural beliefs must be considered when selecting a boot for procurement since all will influence a person's willingness to carry and wear a boot.

For military demining, the value of the conventional boots examined is called into question. Even the best of the conventional boots did not provide significant protection against the explosive equivalent of most existing AP mines. While some conventional boots offered some protection against 25g C4, few AP mines are this small. Given that such a diminutive threat is rarely seen and that there can be no guarantee that it would be the singular threat in-theatre, the authors recommend that all conventional demining boots be removed from service until there are major advances in blast attenuation capabilities of materials or boot design. Issuing these conventional demining boots to soldiers in-theatre could instill a false sense of security and may result in unnecessary risk-taking, with dire consequences, unless the limitations of the protection are clearly stated. At this time, those limitations render the wearing of conventional demining boots both potentially dangerous and inadvisable. For humanitarian demining, procurement of PPE is often more dependent on human factors affecting convenience, like weight and stability, than on blast protection. Likely none of the boots tested during this research are acceptable in most humanitarian demining theatres.

Foot protection is only one element in the PPE suite worn by the deminer. Helmets, visors and body protection will almost certainly complement the footwear. The fragmentation threat posed by all boots, and in particular the Fevam and Med Eng products, will require deminers to protect themselves accordingly with both upper and lower body armour.

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Sommaire

On a évalué la capacité de protection de huit bottes de déminage, disponibles sur le marché, contre le souffle provenant de substituts de mines antipersonnel les à effets de souffle. On a examiné deux types de bottes: les bottes de déminage traditionnelles (dont celles manufacturées par Wellco® Enterprises Inc., DIS Design / Anonymate, Zeman Shoe Ltd., Force Ware GmbH, et Aigis Engineering Solutions Ltd.); et des bottes de style plate-forme (dont celles manufacturées par Fevam America Inc, the Samad Rubber Works Ltd., and Med-Eng Systems Inc.).

La technique utilisée pour tester toutes les bottes provient de la méthodologie de l'OTAN visant à tester l'équipement de protection personnelle (EPP). De plus, des membres inférieurs de remplacement frangibles ont été utilisés pour évaluer les blessures à la jambe. Un chirurgien traumatologue expérimenté, qui ne pouvait pas voir l'équipement de protection utilisé, a documenté toutes les blessures subies par chaque jambe, fait la somme des blessures et établi un Indice de trauma dû aux mines (ITM).

Chaque test utilisant une botte de déminage traditionnelle contre une charge de 50 g (environ la taille d'une mine VS50) ou une charge de 75g (légèrement inférieure à la taille d'une mine PMA-2) aurait résulté en une amputation – à la seule exception de la botte Force Ware. Un seul test utilisant la botte Force Ware contre une charge de 50g a indiqué qu'il serait possible de récupérer le membre. Tous les tests ayant une plus petite charge (25g) ont cependant résulté en amputations ce qui suggère que soit le test de 50g était une anomalie soit la réponse de la botte à une charge supérieure cause, contre toute attente, moins de dommage à la jambe. Il est clair qu'il faut étudier la question de manière plus approndie. Les trois bottes, Aigis, Wellco et Anonymate, testées contre des mines AP de remplacement de 25g auraient résulté en des membres récupérables mais devant subir une opération. Deux des trois bottes Zeman testées auraient probablement résulté en des membres récupérables mais l'une d'entre elles auraient exigé une amputation. La botte American Combat aurait exigé des amputations pour les trois essais qui les utilisaient.

La plate-forme Fevam et les bottes Samad Rubber Works ont été évaluées en nombre limité. Deux essais ont été effectués avec la plate-forme Fevam – l'essai conduit avec une charge de 75g a résulté en un membre récupérable mais non l'essai effectué avec une charge de 50g. Ceci indique que ce test exige également d'être examiné plus en profondeur. Dans les deux essais conduits avec la botte Samad Rubber Works – les tests de 25g et 50g ont tous deux résulté en amputation des jambes frangibles de remplacement. La botte de Med-Eng Systems Inc., aussi connue sous le nom de botte araignée, n'a pas été évaluée dans cette série de tests. Le ministère de la défense des États-Unis avait conduit des tests sur cette botte auparavant. Depuis ces tests, la botte Med-Eng a la réputation d'être efficace contre une charge de 200 grammes de C4.

Bien qu'une botte ait un bon rendement contre les effets de souffle, il y a d'autres problèmes qui lui sont associés dont en particulier leur poids excessif et la diminution de la mobilité. On doit aussi prendre d'autres facteurs en considération tels que le

terrain, le confort et les croyances culturelles lors de la sélection d'une botte à l'achat puisque tout aura une influence sur la volonté de la personne à transporter et à porter des bottes.

La valeur des bottes traditionnelles examinées est remise en question en ce qui concerne le déminage humanitaire. Même la meilleure des bottes traditionnelles ne procure pas de protection importante contre l'explosif équivalent à la plupart des mines AP existantes. Quelques bottes traditionnelles offrent une certaine protection contre 25g de C4 mais peu de mines AP sont aussi petites. Étant donné qu'on fait rarement face à une menace aussi diminutive et qu'il n'existe aucune garantie qu'elle serait la seule menace dans le théâtre, les auteurs recommandent que toutes les bottes de déminage traditionnelles soient retirées du service jusqu'à ce qu'il y ait des progrès majeurs dans le domaine des capacités d'atténuation de souffle des matériaux ou du concept des bottes. Distribuer ces bottes de déminage traditionnelles aux soldats dans les théâtres pourrait procurer un faux sens de sécurité et pourrait résulter en des prises de risque non nécessaires ayant des conséquences graves, à moins que les limites à la protection soient clairement mentionnées. À présent, ces limites font que le port des bottes de déminage traditionnelles est à la fois potentiellement dangereux et non recommandable. Pour le déminage humanitaire, l'achat d'EPP dépend plus des facteurs humains, ayant trait à des raisons pratiques, telles que le poids et la stabilité que de la protection contre le souffle. Il est probable qu'aucune des bottes testées durant cette recherche ne soit acceptable dans la plupart des théâtres de déminage humanitaire.

La protection du pied n'est qu'un des éléments d'EPP porté par le démineur. Les casques, visières et la protection du corps complémentent certainement la chaussure. La menace de fragmentation que posent toutes les bottes et en particulier les produits Fevam et Med Eng, exige que tous les démineurs se protègent en conséquence, avec une armure protégeant la partie supérieure et inférieure du corps.

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1. Introduction

Current commercially available blast mine foot protection systems use various strategies to prevent or reduce injuries due to mines.

Inflatable boots and mine mattresses, for example, are designed to prevent injury by distributing the weight of the wearer over a large area to minimize the pressure exerted on the ground. This type of footwear is beneficial when a mined area has to be traversed quickly in a case where an injured person must be removed from a minefield. For military demining, this type of footwear may be useful when a minefield must be breached rapidly in order to move troops and equipment past an obstacle.

Other boots, like conventional boots and the Samad Rubber Works boot, attempt to reduce injury by combining standoff with layered structures and materials intended to absorb, dissipate, or deflect energy, thereby attenuating the blast. It should be noted that injury prevention footwear may also serve as an injury reduction.

A demining boot with a good blast attenuating capability may be useful when marking out mined areas in humanitarian efforts. In these cases, some degree of protection is desired, but comfort and mobility are of high importance. The same demining boot may also be useful for military engineers who provide advisor support of in-theatre deminers or those who may be tasked with demining small areas when establishing camps or clearing main routes.

Blast attenuation is not the only criterion to be considered when choosing a demining boot for procurement. Depending on the situation, other factors such as mobility, terrain, weight, comfort, and cultural beliefs greatly influence a person's willingness to carry and wear a boot. These factors must be individually assessed according to the specific situation since even the best protection is useless if not worn. Boot fragmentation must also be considered since the fragments themselves may be potentially harmful or lethal.

Additional factors involved in boot procurement are being documented and investigated by DRDC Suffield and CCMAT. This report examines solely the blast attenuating capabilities of eight commercially available demining boots. These boots were tested against 25, 50, or 75 grams of Composition 4 (C4) explosive contained in surrogate AP blast mine cases.

2. Materials and Methods

2.1 Commercially Available Demining Boots

There are two main styles of demining boots: conventional boots and platform boots. A conventional boot looks like a standard combat boot with a thicker sole. Five conventional demining boots have been assessed including those manufactured by Wellco® Enterprises Inc., DIS Design / Anonymate, Zeman Shoe Ltd., Force Ware GmbH, and Aigis Engineering Solutions Ltd. (Note that the Wellco boot is considered here as both the blast boot and overboot. The two components are never separated in these trials.) Platform style boots are usually designed to attach onto a combat boot. A limited number of tests were conducted with two platform boots including those manufactured by Samad Rubber Works Ltd. and Fevam America Inc. Tests were not conducted with the Med-Eng Systems Inc. boot because of numerous tests previously conducted with them [1]. The data from that report was used to compare the Med-Eng boots to the other boots tested here.

Table 1 shows each boot with their corresponding weights and standoffs. The boot weight quoted for each boot type is the average of three separately weighed boots. If the weight of the boot was provided by the manufacturers, it was also included in the table. Standoff is the distance measured between the wearer's heel and a flat hard surface. The standoff values are the average of three separate measurements when an 82 kg person was wearing the protection system on a concrete floor.

Table 1. *Selected Boot Specifications*

DESIGNER / MANUFACTURER	IMAGE	WEIGHT OF ONE BOOT		STANDOFF
		kg	***lbs***	***mm***
Combat Boot		1	2.2	50

Wellco® Enterprises Inc.		2.3 (both blast boot and overboot) (manufacturer data: 1.04 kg for each boot component)	5.0	117
DIS Design and Anonymate		2.0	4.4	77.5
Force Ware GmbH		2.9	6.4	72
The Zeman® Shoe Company		2.0 (manufacturer data: 2.98 kg)	4.4	73
Aigis Engineering Solutions Ltd.		2.4	5.4	82
Med-Eng Systems Inc.		2.9 (boot only)	6.4 (boot only)	194

Samad Rubber Works Ltd.		3.2 (boot only) 4.2 (boot and combat boot)	7 (boot only) 9.2 (boot and combat boot)	84
Fevam America Inc.		2.9 (boot only) 3.9 (boot and combat boot) (manufacturer data: 2.6 kg)	6.4 (boot only) 8.6 (boot and combat boot)	176

2.2 Frangible Surrogate Lower Leg

Thirty-three frangible surrogate lower legs (FSLLs), developed by the Australian Defence Science and Technology Organization (DSTO) [2], were obtained for this study. The FSLL can be seen in Figure 1. To preserve the ballistic gelatin, all FSLLs were maintained at 4°C in a cooling unit until just prior to the test.

Figure 1. *FSLL bones (left) and soft tissue (right) with boot attached*

2.3 Explosive Threat

The trial charge sizes (25g, 50g, or 75g) of Composition 4 (C4) were packed in Dupont Adiprene® containers, each having a height-to-diameter ratio of 35% based on a review of AP mine geometries. The charges were bottom-initiated with RP-87 detonators.

2.4 Trial Procedure

The following technique and conditions that were used to test all boots were adopted from a NATO methodology [3] for testing personal protective equipment (PPE).

Before each trial, the test boot was put on an FSLL and laced up tightly. The surrogate leg was attached to a 25kg piston shaft so that the FSLL and boot could only move linearly along the vertical shaft axis, as shown in Figure 2. In this vertical position, the surrogate limb was considered fully extended, according to NATO test methodology. The piston shaft was lowered to the surface of the sand to mark the location of the centre of the heel where the charge would be buried and to set the piston stop that held the boot at a zero kg pre-load condition. The piston shaft was then raised to bury the explosive charge.

The explosive charges were buried in dry 20/40 sand (also referred to as number 7 sandblasting sand) that was loosely poured into a 460mm x 610mm x 460mm (depth) soil container made of 12mm thick mild steel. A screed was used to loosely level the sand both before and after the burial of the charge. The charges were buried with 2cm overburden at the location of the center of the heel previously marked when the piston was lowered. The spot beneath the center of the heel was chosen as the charge burial location because it is considered the worst case scenario in terms of delivering damage to the human lower extremity.

The raised piston shaft was then lowered to the piston stop. The site was cleared, instrumentation verified, a final safety check made and the explosive charge was initiated.

Each of the conventional boots (Wellco®, Anonymate, Zeman®, Force Ware, Aigis) was tested once against 75g of C4, once against 50g of C4, and three times against 25g of C4. Three charge sizes were screened to determine which should be used for repeated trials: 75g, 50g, and 25g. The two platform boots (Fevam America Inc., Samad Rubber Works) were both tested in limited numbers.

A post-trial fragment search was conducted to collect as much of the debris as possible. Within reasonable limits, all major components, such as wedges, plates and material fragments were gathered after each trial. The remainder of each protection system was left on the FSLL, which was then removed from the piston shaft, wrapped in plastic film wrap and returned to the cooling unit until the medical assessments were performed.

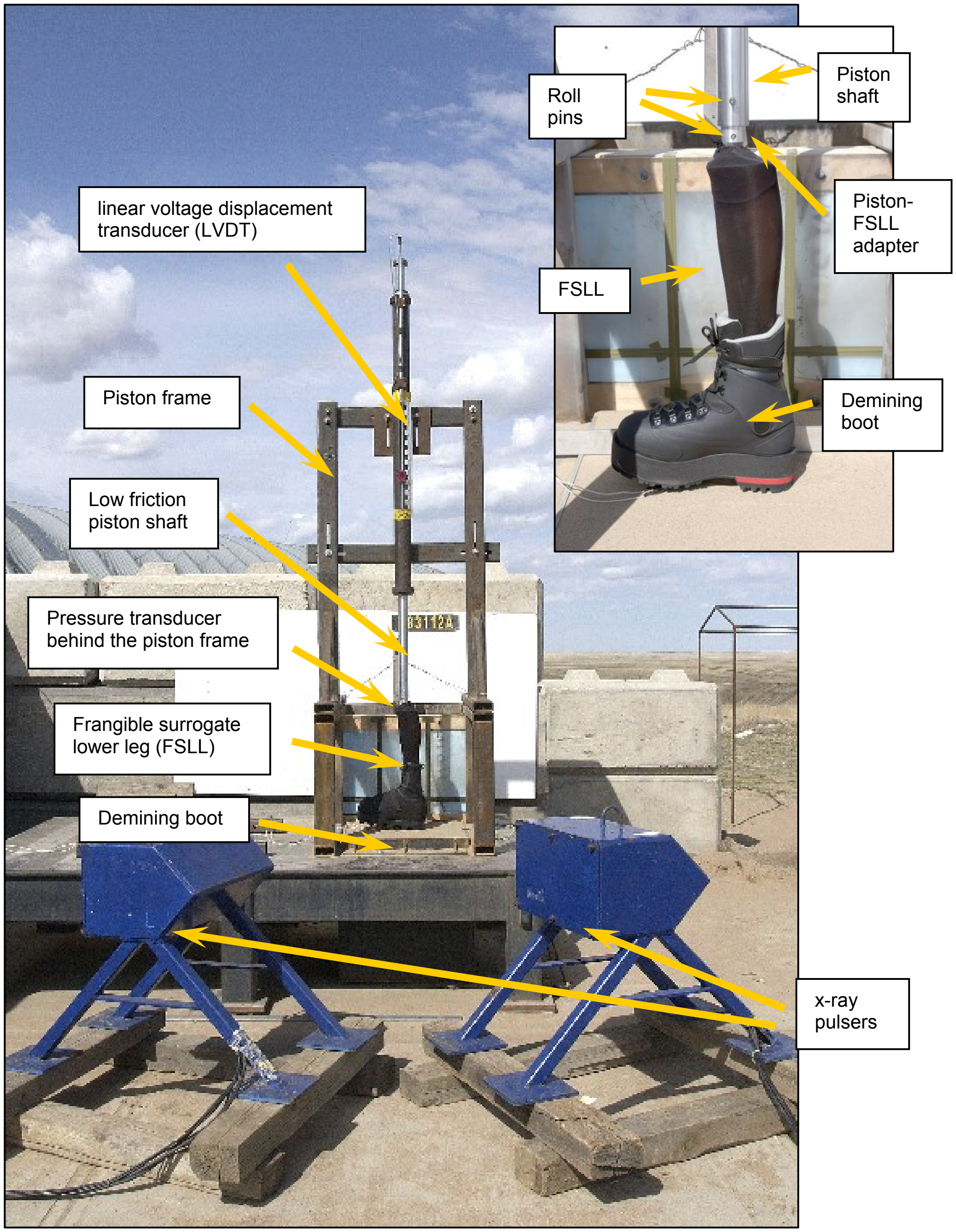

Figure 2. *Piston shaft apparatus*

2.5 Post Trial Medical Assessments

Dr. Colonel Ian Anderson, experienced in both civilian and military casualties, examined each FSLL, post trial. Dr. Anderson has been involved with the DRDC Suffield protection program since its inception and he has extensive experience with both cadaver and FSL dissections. Given the resources available to the project and Dr. Anderson's background, a single medical opinion was deemed appropriate.

The surgeon was blinded to both the protective equipment and the size of the surrogate mine. Examinations were video taped and each dissection was documented with a series of photographs, as shown in Figure 3.

Figure 3. *Examples of FSLL damage for effective and ineffective demining boots*

Figure 3a. The boot used for this specimen was NOT effective against 75g of C4. (Note the pieces of the shattered heel bone)

Figure 3b. This boot used for this specimen was effective against 25g of C4. (Note the bones and tendons are intact)

The specimen was examined in detail paying particular attention to the completeness of the specimen, perforations of the nylon mesh, evidence of contamination, joint stability, splits and defects in the gelatin, and the integrity of the surrogate bones.

After documenting all of the injuries associated with a given specimen, the surgeon summed the total of the injuries for each specimen and assigned each FSLL a Mine Trauma Score (MTS). The MTS was developed during the Lower Extremity Assessment Program [4] to score the injuries observed against cadaver limbs during trials to examine the effectiveness of protective footwear against AP blast mines. The table below lists and describes the MTS scores [5].

Table 2. *Mine Trauma Score (MTS)*

SCORE	***INJURY***	***SURGERY REQUIRED***
0	Minimal	No major surgery required
1	Closed	Surgery required and limb is salvageable
1A	Open contained	
1B	Open contaminated	
2	Closed	Surgery required; definite below knee amputation
2A	Open contained	
2B	Open contaminated	
3	Open contaminated	Surgery required; could lead to either below or above knee amputation
4	Open contaminated	Surgery required; definite above knee amputation

NOTES:

Closed injury: any injury to the lower extremity that does not violate the skin, thereby minimizing the risk of infection.

Open contained injury: any injury to the lower extremity that violates the skin (lacerations, tears), but is not contaminated by the outside environment because the inner footwear was not compromised.

Open contaminated injury: any injury to the lower extremity that does violate the skin and has contamination of the soft tissues and bones from the environment where the blast occurred.

3. Results and Discussion

The results of the trials are summarized in Table 3, Figure 4, Figure 5, and Figure 6. For all five conventional demining boots except the Force Ware boot, FSLLs subjected to 75g and 50g charges sustained severe open contaminated injuries that would have definitely resulted in a below knee amputations. The Force Ware boot was the only footwear that may have resulted in a salvageable limb against a 50g charge because the surgeon felt that the injury could be treated with either an amputation or a limb sparing reconstruction. Since the FSLLs in the Force Ware boot would have required amputations against all 25g shots, the results for the 50g charge appeared anomalous. However, additional tests should perhaps be conducted with the Force Ware boot using charge sizes of approximately 50g or C4 to confirm this.

Except for one Zeman boot, all three tests using each of the Aigis, Wellco, Anonymate, and Zeman boots against 25g charges resulted in MTS scores of 1A and 1B, indicating salvageable limbs. However, even if the FSLL received the same injury score, the actual injuries varied a great deal. In the case of all three tests with the Anonymate boot, one test with the Zeman, and one test with the Wellco, the doctor assigned values of 1A and 1B, but expressed an uncertainty about whether the limbs were salvageable because of significant and/or multiple fractures. However, he felt that the limbs were “probably” salvageable and the scores with 1 reflected this fact. Two of the three Aigis and Wellco boots tested against 25g surrogate AP mines also received MTS scores of 1A and 1B, but would have resulted in definitely salvageable limbs as the injuries typically consisted of joint dislocations, limited fractures, and minimal soft tissue damage. The third test with the Aigis would have resulted in a salvageable foot, but significant soft tissue injury. The third test with the Wellco would have likely resulted in a viable leg, but the fractured calcaneous and forefoot dislocation would have made this a difficult injury. The FSLLs using the American Combat boots required amputations for all trials performed for all charge sizes.

The three repeat trials did not show completely consistent injuries and do not allow for statistically significant conclusions. However, the results documented show a trend similar to various tests completed by the United States Department of Defence [1, 4] where the conventional boots tested do not protect against medium and large charge sizes, but do provide some protection against small charges.

The discrepancies in the tests could be the result of small differences in the explosive event because of the way the charge was packed, the depth of burial, the soil characteristics, the orientation of the charge, subtle differences in the initiation train or in how the explosive loading was delivered up to the leg.

The two platform boots (Fevam platform and Samad Rubber Works mine shoe) were not part of the primary focus of this study on demining boots. For both, a limited number of cases was examined because there was a restricted number of sample boots available for testing. The Fevam platform was only subjected to two tests and greater damage was observed at 50 grams than at 75 grams C4. Like the Force Ware conventional boot result, this indicates that further investigation may be warranted. As previously stated, variations in the explosive event itself could account for some of these discrepancies. Nevertheless, the test indicates that the Fevam platform might have the potential to better protect against larger mines than other boots tested, and further tests with a greater number of boots should be considered.

Table 3. *Summary of Results*

BOOT	CHARGE SIZE	MTS INJURY SCORE
Combat boot	25g	2B
		2B
		2B
Wellco	75g	2B
	50g	2B
	25g	1B
		1A
		1A
Anonymate	75g	3
	50g	2B
	25g	1B
		1B
		1A
Forceware	75g	3
	50g	1B or 2A
	25g	2B
		2B
		2A

Zeman	75g	3
	50g	3
	25g	2A
		1B
		1A
Aigis	75g	2B
	50g	2A
	25g	1A
		1B
		1A
Favam America Inc.	75g	1B
	50g	2B
Samad Rubber Works	50g	2B
	25g	2B

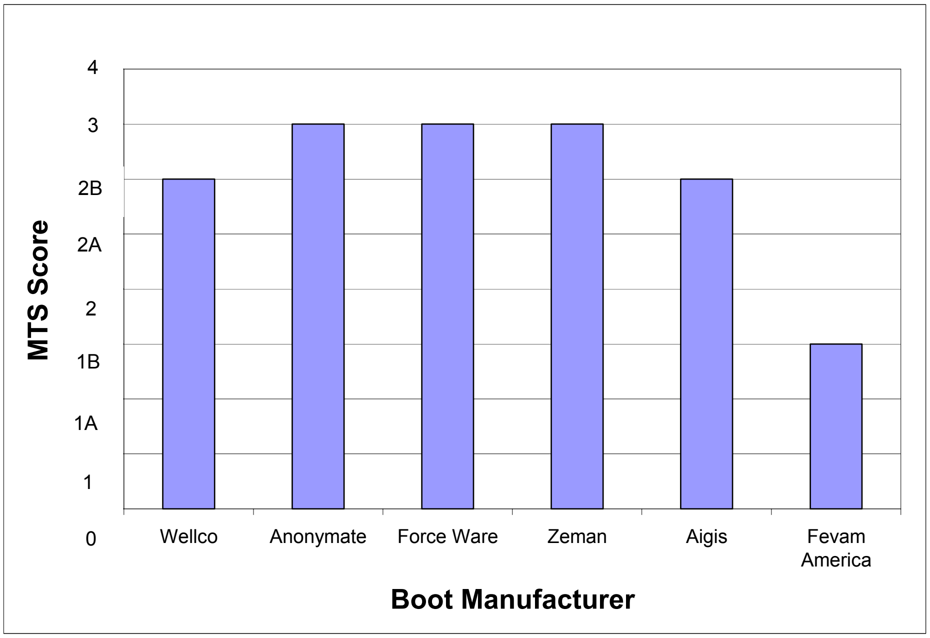

Figure 4. *MTS injury scores for 75g C4 shots*

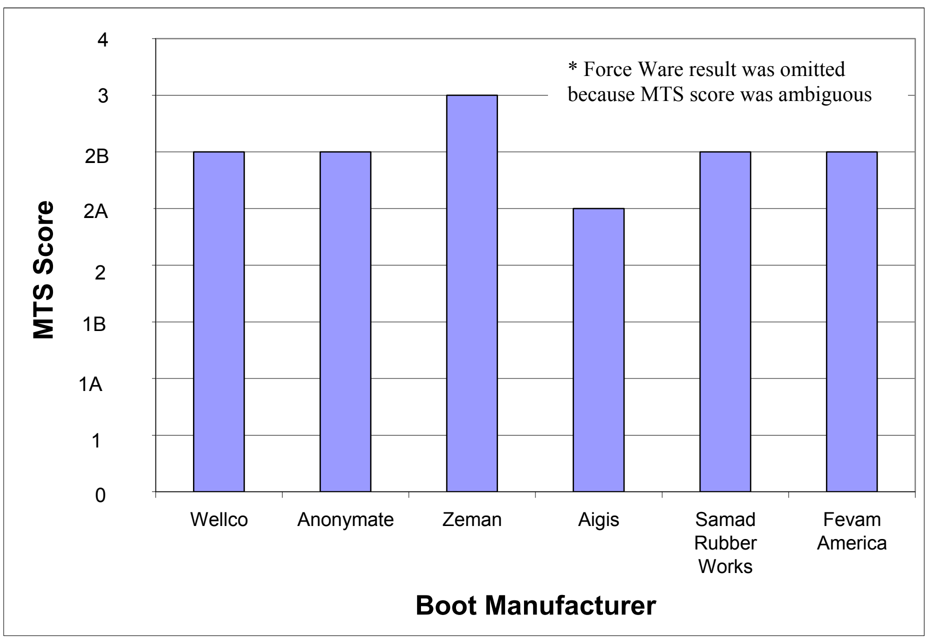

Figure 5. *MTS injury scores for 50g C4 shots*

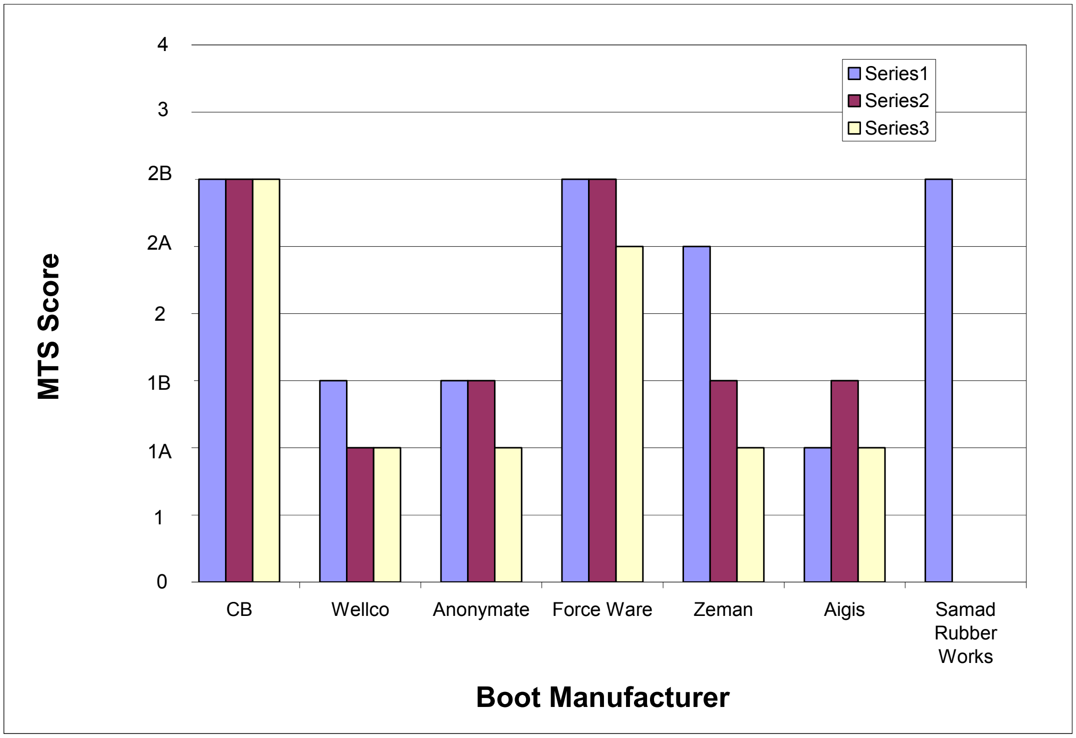

Figure 6. *MTS injury scores for 25g C4 shots*

The Med-Eng boot was not tested in this series because of the extensive testing completed by the United States Department of Defence [1]. From those trials, the Med-Eng boot consistently prevented amputation for all test configurations for charge sizes up to 200g of C4. However, there are other problems associated with these two platform boots, especially the fragmentation, mobility, and weight issues – all of which must be considered prior to the procurement of any demining footwear.

It should be noted that dry sand was used, and the potential damage to the leg may be more severe in different soil types and conditions [6].

4. Conclusions

For military demining, the value of the conventional boots examined in this report is called into question. Even the best of the conventional boots did not protect against the explosive equivalent of most existing AP mines for the number of tests conducted, under the test conditions and internationally accepted protocol described. In these tests, protection was only seen at the 25g charge size and such a diminutive threat is rarely seen in the field. AP blast mines are more commonly equivalent to at least 50g of C4 and the single, possibly anomalous, result for the Force Ware boot aside, these conventional demining boots were ineffective in providing protection at this charge size. The authors recommend that all conventional demining boots be removed from service until major improvements are made in boot materials and design. Given that these boots add weight and decrease overall ease of mobility, issuing demining boots to soldiers in-theatre serves to instill a false sense of security and could result in the taking of inadvisable risks with dire consequences unless the limitations of the protection were clearly stated. At this time, those limitations render the wearing of conventional demining boots unnecessary and potentially dangerous.

In the case of humanitarian demining, procurement of PPE is very dependent on human factors, especially stability, mobility, and comfort. None of the boots tested during this research are likely acceptable in most humanitarian demining situations.

Only two platform boots were tested, and only in limited numbers. Two Fevam America Inc. Demining Sapper Platform boots were tested; the limb was salvageable for the 75g C4 case. Since the 50g C4 limb would have required an amputation, either trial may have been anomalous. Although the 75g case may indicate that the Fevam platform has a potential to reduce mine injuries, as with the Force Ware boot, such a result requires verification. Additionally, this boot distributes the weight of the wearer (minimizing the chance of detonating a mine) while elevating the person above the ground surface (reducing the potential injury if a mine is detonated). This boot merits more attention, and the authors advise that the Fevam platform be further investigated for both its mine injury prevention and reduction capabilities.

The Foot Protection System by Med-Eng Systems Inc. is recommended for use in cases such as defining mined areas prior to demining operations, or when following mechanical clearance equipment. In the former case, the wearer would be working slowly, not getting up and down from their knees very often, and would have maximum blast protection. In the latter case, the lower limb is most vulnerable and the risk already reduced. The concerns with these boots are the fragmentation threat, the lack of stability on rough or rocky terrain, the difficulty in mobility, and the added weight.

It is understood that demining foot protection is one element in the PPE suite worn by the deminer. Helmets, visors and body protection will almost certainly complement the footwear. The fragmentation threat posed by all boots, and in particular the platform boots such as Fevam and Med Eng products, will require deminers to protect themselves accordingly with both upper and lower body armour.

Future testing and evaluation should be conducted with the Force Ware boot and Fevam America platform to verify their effectiveness at larger charge sizes.

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Eight commercially available demining boots were tested for their ability to provide protection against the effects of surrogate anti-personnel blast mines. Boot performance was determined based on post-blast evaluation by a trauma surgeon of frangible surrogate lower legs (FSLLs). None of the conventional demining boots tested provided significant protection.

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