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Prototype Gen III Fragmentation Vest Biomechanical Evaluation

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April, 2000

Prototype Gen III Fragmentation Vest Biomechanical Evaluation

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Table of Contents

1.0 Introduction 5
2.0 Methods 5
  2.1 Load Carriage Simulator 5
  2.2 Range of Motion Testing 6
3.0 Load Carriage Simulator Results 7
  3.1 Relative displacement of Prototype Frag Vest 7
  3.2 Skin Contact Pressures 8
  3.3 Reaction forces and Moments 9
  3.4 Compatibility with CTS Tactical Assault Vest 10
4.0 Resistance to Torso Motion Results 11
  4.1 Resistance to Motion about a Vertical Axis (Torsion) 11
  4.2 Resistance to Forward Bending 13
  4.3 Resistance to Sideways Leaning 14
5.0 Conclusions and Recommendations 15
6.0 References 17

ABSTRACT

The objective of this work was to assess the biomechanical performance of the current issue fragmentation vest, the Gen II 97-F with lap joint closure at both shoulders, the Gen IIIA with a side opening creating a continuous shoulder and the Gen IIIB with an asymmetrical one shoulder closure style.

The dynamic behaviour of each design and its' impact on the user (asymmetrical loading, high hip reaction forces, and high contact pressures on the skin) was quantified using the Load Carriage Simulator. Designs were assessed for restriction to upper torso mobility using standard testing on the Load Carriage compliance tester. As well, the cause of any poor performance was reported. Finally, each fragmentation vest design was evaluated for compatibility with the proposed Tactical Assault Vest (TAV).

Results and conclusions fell into two categories; factors related to user discomfort and factors related to user mobility.

User Discomfort

- The shoulder lap joint closure on the Gen II-97 and Gen IIIB designs caused pressures expected to induce appreciable user discomfort when worn under a loaded (98 N) tactical assault vest, (TAV). The shoulder region of the Gen IIIA design demonstrated a smooth acceptable distribution of pressure.
- The hidden female Fastex® connector located under the lower front pocket of the TAV caused very high local contact pressures (>89kPa). Elasticity of the mesh on the TAV allowed the top of pockets to rotate away from the body, this pressed the inside bottom edge of pocket contents into the body.

Resistance to Torso Motion

- The Gen II -97F had the highest resistance to torso rotation about a vertical axis , followed by the Gen IIIB with 0.473 N-m. The Gen IIIA offered the least resistance to twist with 0.319 N-m. As this motion, and lateral bending, are required for a walking gait, increased resistance is expected to result in higher energy costs to the user over long duration activities.[6]
- During 10° of lateral bending, the side closure design in the Gen IIIA and Gen II 97F reduced the bending moment required with the Gen IIIA having almost no resistance to lateral motion. The lapped front closure on the Gen IIIB had twice the lateral resistance of the Gen II 97F.
- The longer torso length in the Gen III designs required greater forward bending effort compared to the shorter Gen II design. If the protective material could be hinged, this moment would be reduced.

The Gen IIIA prototype design was found to offer superior performance compared to the current issue fragmentation vest for the following: distribution of the TAV load onto the shoulders, reduced resistance to lateral bending and reduced resistance to rotation of the torso about the vertical axis.

Edges, layers and discontinuities will cause unacceptable contact pressures when externally loaded. This was shown at the shoulder and on the front of the hip. Combinations of equipment need to be defined and considered at the design stage. Connectors or other discontinuities, particularly the connector under the lower front pocket of the TAV, should be moved from locations where a pocket might rest directly on it.

The elasticity of the TAV mesh may contribute to user discomfort by allowing the top of loaded pockets to move away from the body, causing the inside lower edge to pivot on the body. If this occurs on top of a hard connector, underlying tissue can experience extreme point loading.

1.0 Introduction

The major crown project L2646 "Clothe the Soldier" is intended to acquire improved personal protective equipment for Canadian Forces soldiers. In support of this program, the Defence and Civil Institute of Environmental Medicine (D.C.I.E.M.) is supporting the development of an improved fragmentation vest using the knowledge gained and the biomechanical evaluation tools developed under the APLCS R&D programme, [1,2,3]

Two prototype vest designs have evolved from field experience with the current issue fragmentation vest, the Gen II –97F (Pacific Body Armour Ltd). In order to assess the merits of each design, it is necessary to determine their biomechanical effect on the soldier. It is possible that the asymmetrical closure may cause an unbalanced loading of the body or a closure method may cause high contact pressures on the skin. As well, variation in the closure design (shoulder or single or double side) will determine the geometry of the underlying multi-layer ballistic fill which in turn can affect the mobility of a users upper body.

The objective of this work is to assess the biomechanical performance of each prototype design, identify the causes of poor performance, identify potential problems for end users, and test each frag vest design for compatibility with the proposed Tactical Assault Vest (TAV). In total, three vest designs will be evaluated: the Gen II-97F as a baseline and the Gen III-A and B prototypes.

The dynamic behaviour of each design and its' impact on the user will be quantified using the Load Carriage Simulator. The effect of each design on the mobility of the torso will be measured using standard testing on the Load Carriage compliance tester.

2.0 Methods

2.1 Load Carriage Simulator

The Load Carriage Simulator (LC Sim) and the standard test protocols have been reported previously. [1,2,3] It consists of a representative 50 percentile male torso, anthropometrically weighted and covered in an artificial skin analogue mounted on a programmable displacement table. A six degree of freedom load cell is located at the base of the torso which allows the calculation of hip joint reaction forces. A Polhemus® Fastrak system is used to record the relative displacement of the prototype vest with respect to the upper torso. Contact pressure distribution is measured using a Tekscan® FScan system, using the 9810 sensor. These thin sensors (<0.2 mm) cause minimal disruption of the contact surfaces. They have a spatial resolution of 12.7 mm and contain 96 active sensing areas covering approximately 76 x 200 mm. Six sites were monitored for their contact pressures. Sensor locations included:

1. Left anterior shoulder
2. Right anterior shoulder
3. Left posterior shoulder
4. Right posterior shoulder
5. Left Hip, iliac crest
6. Right hip, iliac crest

Table 1. Identity and description of fragmentation vest designs.

Designation	Status	Description
i. Gen II– 97F	current issue	- lap joint at top front of both shoulders, - back panel laps over front to form side closures, both sides - Velcro® straps (2 each side) restrain side closures - collar detachable, snap and Velcro® - collar has reduced profile at back of neck - neck opening, approximately 190 mm
ii. Gen III A	Prototype	- no shoulder joint, continuous shoulder contour - back panel laps over front to form side closures, both sides - Velcro® straps (2 each side) restrain side closures - collar detachable, snap and Velcro® - collar has reduced profile at back of neck - neck opening, approximately 190 mm
iii. Gen III B	Prototype	- asymmetrical (single side) left shoulder closure, - front and back panels part on left side only - Velcro® on overlap of front and back panels restrains the closure.

Each fragmentation vest prototype was fitted on the LC Sim manikin over the CF combat shirt. The new TAV was loaded with a representative fighting load of dummy kit items, consisting of the items listed in Table 2.

Table 2. Fighting load definition and location

Number	Item	Location on TAV	Mass (kg)
1	C9 drum	right side of TAV	2.25
2	C7 magazines	upper front left	0.90
2	C7 magazines	upper front right	0.90
2	Smoke grenades	front of C9 pocket & water canteen	0.88
2	Frag. grenades	front right auxiliary pocket	0.90
1	Water canteen	left side above hip	1.00
1	TAV empty	-	2.24
		Total Weight	98 N (20 lbs)

The TAV was then fitted over a prototype frag vest. Pressure sensors were placed under contact areas, particularly in the shoulder region, and a relative motion sensor was placed on the body of the Frag vest. The LC Sim was programmed to displace the frag vest and torso to simulate walking over level terrain at 100 metres/minute (6 kmph).

2.2 Range of Motion Testing

The Load Carriage Compliance Tester and the standard test protocols have been described in previous reports [1,2]. The apparatus consists of a representation 50 percentile male torso articulated at two points: horizontally at T12 to allow shoulder/hip counter-rotation; and at the waist to allow forward and lateral bending. A single degree of freedom is active at any given moment. The apparatus is instrumented with load cells to record a time history of the forces required to move the torso and attendant equipment through a set range of motion. This information is converted into a stiffness characteristic for the equipment being tested. [3]

3.0 Load Carriage Simulator Results

3.1 Relative displacement of Prototype Frag Vest

A Fastrak® position sensor was mounted on the posterior surface of each fragmentation vest, on the midline of the body in the upper shoulder region. The magnetic source (the origin) for the Fastrak® was rigidly mounted to the manikin approximately 360 mm distant. Relative motion of each Frag vest was determined by recording the position vector for the vest sensor during dynamic testing. Results are summarized in Table 3 where V_X, V_Y, and V_Z are the vectors shown in Figure 1.

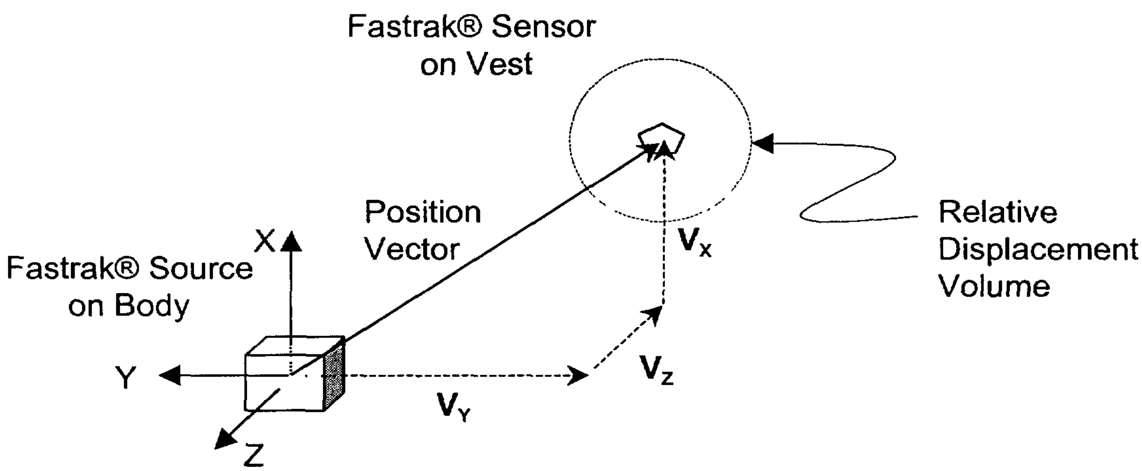


Figure 1. Definition of the relative displacement vectors and displacement volume. X is superior/inferior, Y is anterior/posterior and Z is medial/lateral with respect to a wearers' body.

Table 3. Summary of the Relative Displacement of Frag Vest Designs with respect to the torso. Average of 5 samples, 10 second sample duration at 30 Hz sampling frequency. Torso displacement function +/- 25 mm at 1.8 hz, simulated walking .

Prototype Gen II 97F

Relative Displacement	Vector V_X Superior / Inferior	Vector V_Y Anterior / Posterior	Vector V_Z Medial / Lateral
Max. (mm)	52.20	152.60	313.80
Min. (mm)	51.60	152.00	313.50
Max – Min (mm)	0.60	0.60	0.30
Volume (mm^3)		0.11	

Prototype Gen III A

Relative Displacement	Vector V_X Superior / Inferior	Vector V_Y Anterior / Posterior	Vector V_Z Medial / Lateral
Max. (mm)	68.30	154.50	321.10
Min. (mm)	67.80	154.20	320.80
Max - Min	0.50	0.30	0.30
Volume (mm^3)		0.05	

Prototype Gen III B, Asymmetric Shoulder Closure

Relative Displacement	Vector V_X Superior / Inferior	Vector V_Y Anterior / Posterior	Vector V_Z Medial / Lateral
Max. (mm)	31.20	163.90	325.40
Min. (mm)	30.30	163.50	325.00
Max - Min	0.90	0.40	0.40
Volume (mm^3)		0.14	

There is negligible relative motion (< less than 1 mm) between the frag vests and the body for all three designs. This level of motion is not expected to lead to discomfort or decreased load control for the user.

3.2 Skin Contact Pressures

Table 4 is a summary of the location and values of the peak contact pressures recorded during a simulation of walking at 100 m/minute (6 kph). Previous studies [Holloway et al, Sangeorzan et al] have shown that skin contact pressures of > 16 kPa can cause the complete cessation of blood flow to underlying tissue. Tissue damage often begins subcutaneously when underlying bony structures cause crushing of the loaded deep muscle, [Daniel et al]. In certain circumstances, much higher distributed pressures (up to 120 kPa) can be endured passively for up to several hours without necessarily causing gross tissue damage [Daniel et al.] but the reduced ability to oxygenate this tissue will severely limit the ability of the tissue to do work. Previously, pressures > 35 kPa recorded on the LC Sim have been indicative of user reported discomfort [Phase I Report].

Table 4. Peak Contact Pressures - Location and cause, average of 3 samples, 10 second sample duration, sampling frequency of 50 hz.

Location	Gen II	Gen III A	Gen III B
Front Right Shoulder	70 (1)	23	21
Front Left Shoulder	44 (1)	18	46 (1, 3)
Back Right Shoulder	19	13	22
Back Left Shoulder	12	16	16
Hip – Iliac Crest	12	45 (2)	89 (2)

[1] The internal edge of the ballistic fill ends in the area of the clavicle and the Velco® attachment for the collar When the TAV shoulder strap presses down on one (or more) or these discontinuities, a concentrated loading occurs causing contact pressures >35 kPa.
[2] This peak pressure is caused by a combination of TAV features. There is a female slide lock connector for TAV webbing loop hidden on the bottom edge of the TAV behind the lower front pocket. The front panel mesh above the front pocket permits the pocket to rotate outwards away from the body, levering the hidden connector into the front of the hip.
[3] The asymmetry of the design of the Gen III B closure is reflected in the asymmetrical shoulder pressures.

3.3 Reaction forces and Moments

The hip forces and moments induced during simulated brisk walking are summarized in Table 5. TAV loading was identical for each Frag vest. Variations in the results are due to two factors, first, the weight and distribution of this weight will contribute directly to the induced forces at the hip and secondly, the dynamic response of each system of equipment contributes it's own acceleration/deceleration response. The interaction of these two factors can combine to reduce the induced joint load or they may compound and amplify the individual effects.

Table 5. Summary of Force and Moment Analysis

Gen II 97F — Weight of Frag Vest = 24.9 N (5.6 lbs)

	Fx	Fy	Fz	Mx	My	Mz
Max	159.6	106.4	948.8	24.5	32.7	0.7
Min	-31.0	17.7	274.9	-9.9	-48.6	-2.6
Avg	44.8	66.1	649.1	6.0	0.7	-0.6
Max-Min = Delta	190.6	88.7	673.9	34.4	81.2	3.3

Gen III A — Weight of Frag Vest = 26.3 N (5.9 lbs)

	Fx	Fy	Fz	Mx	My	Mz
Max	181.8	115.3	962.1	22.7	30.9	1.9
Min	-28.8	11.1	297.1	-10.8	-53.6	-2.6
Avg	49.4	66.2	660.7	5.7	-1.4	-0.3
Max-Min = Delta	210.6	104.2	665.0	33.5	84.5	4.5

Gen III B			Weight of Frag Vest = 31.6 N (7.1 lbs)			
	Fx	Fy	Fz	Mx	My	Mz
Max	170.7	117.5	975.4	23.2	30.7	1.3
Min	-35.5	20.0	301.5	-11.0	-52.3	-3.0
Avg	50.0	67.0	667.0	5.6	-1.4	-0.3
Max-Min = Delta	206.2	97.5	673.9	34.2	83.0	4.3

All three prototype vests performed well, there was no inherent penalty associated with the asymmetrical closure of the Gen III B design.

3.4 Compatibility with CTS Tactical Assault Vest

All fragmentation vests were tested with the TAV to simulate anticipated field usage and to identify conflicts between the two pieces of equipment.

Gen II and Gen III A, with two side closure straps on each side, were easier to fit to the torso. The independent upper and lower straps with elasticized sections allowed precise adjustment to the closure tension and angle of overlap along the closure. The single overlapping Velcro® lined flap on the Gen III B design required multiple attempts to achieve correct alignment of the closure.

The vest design of the TAV is generally well suited to being worn over a fragmentation vest. A number of minor interference issues were noted during the testing. Some are due to a conflict with a particular fragmentation vest design, others are a result of the TAV materials and the location of its' pockets.

Gen II – 97

1. The internal edge of the ballistic fill that forms a lap joint on both shoulders creates a lump in the region of a users clavicle (collar bone). This location coincides with the site of the Velcro® attachment for the frag vest collar. When a loaded TAV is worn, the load is carried directly on a users shoulders and excessive pressure is exerted by the multiple discontinuous edges of the underlying materials.
2. The TAV vest has a number of one inch wide webbing straps attached to the inside bottom edge. These straps can be tucked up into recessed pockets when not in use. The webbing strap that is located under the C9 drum was detectable through the fragmentation vest and caused a localized pressure of about 25 kPa. Although this is below the general guidelines for tissue pressure tolerance, the highly localized nature and potential for repetitive jarring impact or chaffing on the hip area may combine to cause skin irritation over time.

Gen III A

1. The lower front pocket of the TAV was loaded with a smoke grenade. The compliance of the TAV mesh allows the entire pocket to rotate outwards away from the body. This action presses

the hidden female component of a Fastex connector into the body resulting in high skin contact pressures (>41 kPa.) This fragmentation vest does not extend down far enough to shield the hip and iliac crest.

Gen III B

1. The C9 drum fits in a custom pocket attached to the TAV typically on a soldiers right side. The elastic mesh forming the TAV side panel allows the top of the drum to move outwards away from the body causing the drum to pivot on its lower inside edge. The location of this edge coincides with the head of the zipper on the closure of the Gen III B back ballistic plate pocket. This confluence of design details created a point loading of the body which resulted in a discernable point load in this area. Although the detected pressure was less than the current recommended limit of 14 kPa for continuous exposure, [3] shifting the position of the zipper head or C9 pocket slightly would remove any risk of damage to the soldier or the zipper.

2. The lower front pocket of the TAV was loaded with a smoke grenade. The compliance of the TAV mesh allows this pocket to rotate outwards away from the body. This action presses the hidden female component of a Fastex connector into the body resulting in high local contact pressure (>89 kPa.) Although this fragmentation vest does extend down far enough to shield the hip and iliac crest, an extremely high pressure is induced by the layers of discontinuities and heavy loading in this area.

4.0 Resistance to Torso Motion Results

4.1 Resistance to Motion about a Vertical Axis (Torsion)

This test is usually performed over a +/- 10° rotation which reflects the range of counter rotation experienced during normal walking with loaded rucksacks. It is anticipated that fragmentation vests will be worn during activities requiring much greater trunk mobility such as evasive maneuvers and entering the confined space in vehicles. To accommodate this increased need for flexibility, the rotational stiffness was measured during a +/- 35° rotation about the vertical axis. Results for the three designs are shown in Figure 2 and summarized in Table 6.

Table 6. Summary of torsional stiffness and the moment required to initiate twisting of the torso. Tabulated data is the average of three repeated runs.

Fragmentation Vest	Torsional Stiffness	Initialization Moment
i. Gen II– 97F	+ 0.645 N-m/degree	- 0.7 N-m
ii. Gen III A	+ 0.319 N-m/degree	- 0.7 N-m
iii. Gen III B	+ 0.473 N-m/degree	+ 1.2 N-m

The Gen II design offered the greatest resistance to rotation of the torso, followed by the Gen III A and Gen III B designs in order of decreasing stiffness. The low stiffness of the Gen III B design was due to difficulty in achieving a close fit of the lower torso, this allowed a gap to exist about the waist. As a result, the lower abdomen and hips rotated with minimal contact with the Gen III B vest.

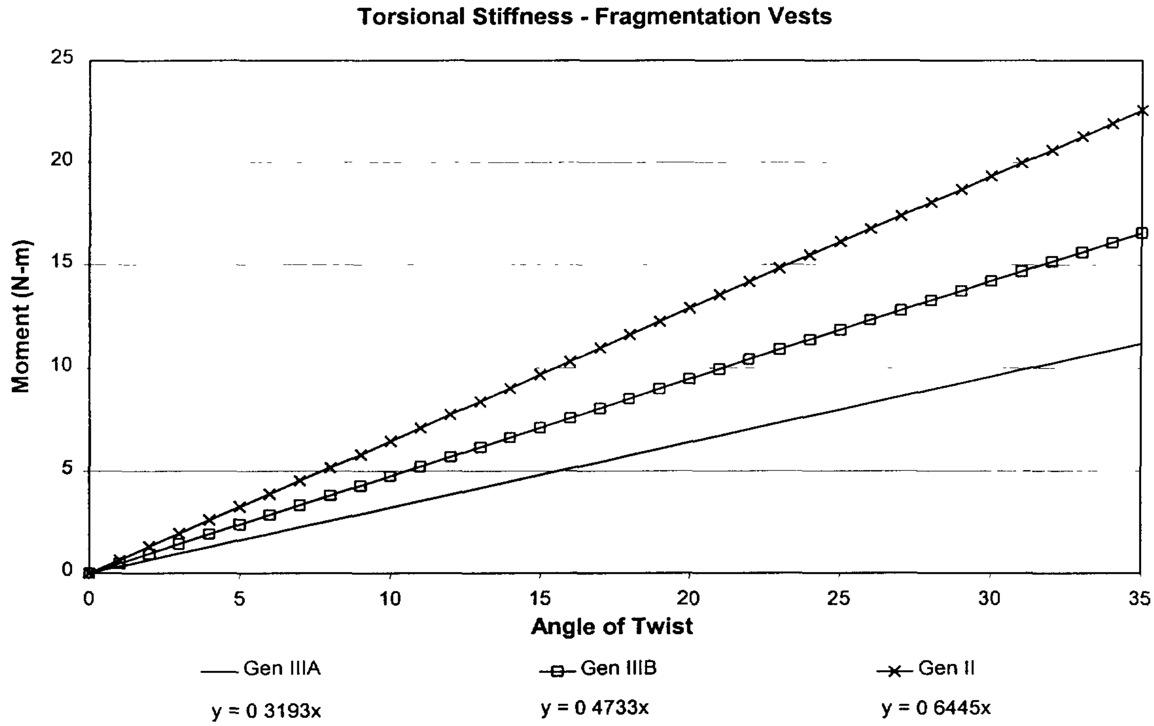
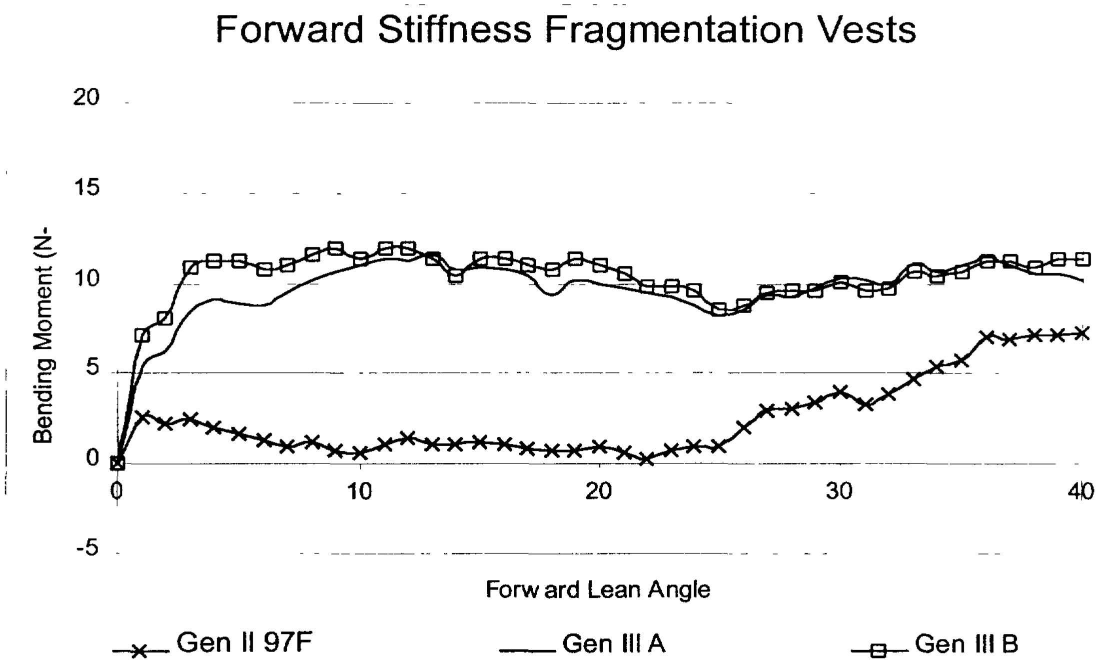


Figure 2 Resistance to torso motion about a vertical axis. The stiffness response, shown above for each fragmentation vest design, was calculated using a least squares fit on the results for three repeat tests.

4.2 Resistance to Forward Bending

The results for the forward bend testing are shown in Figure 3 and summarized in Table 7.

a)



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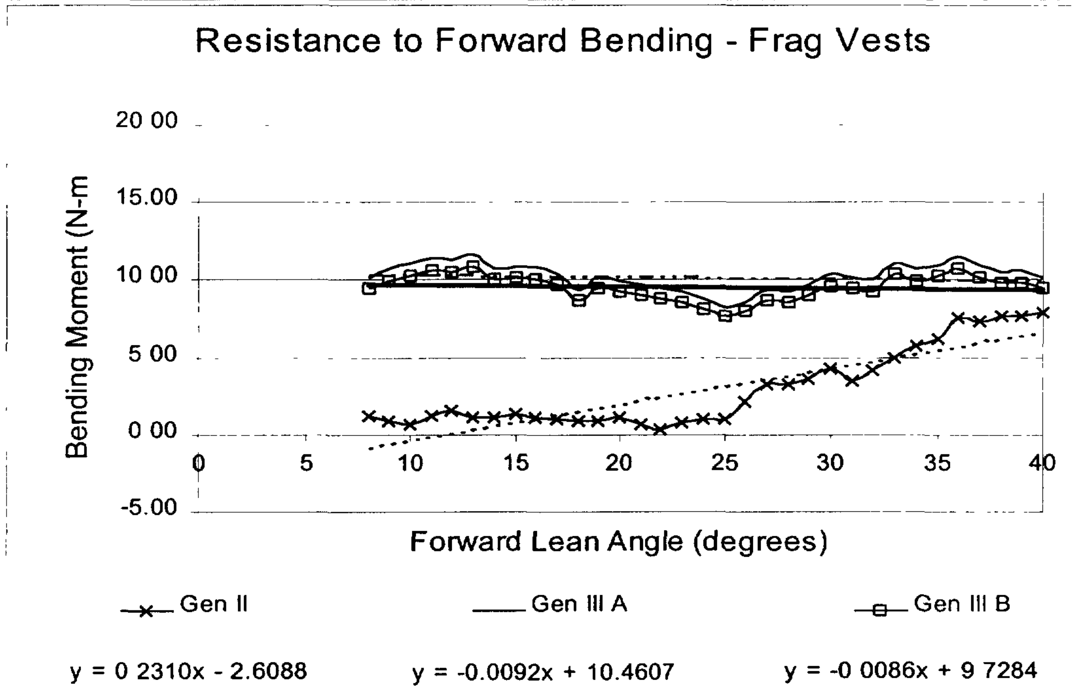

Figure 3. a) A history of the resistance to motion during a +40° forward lean.
b) Range of data used to calculate the forward bend stiffness value.

Table 7. Summary of forward bending stiffness and the moment required to initiate bending.

Fragmentation Vest	Forward Bending Stiffness	Initialization Moment
iv. Gen II– 97F	+ 0.23 N-m/degree	- 2.6 N-m
v. Gen III A	- 0.01 N-m/degree	+ 10.5 N-m
vi. Gen III B	- 0.01 N-m/degree	+ 9.7 N-m

Both the Gen III A and B designs require about 10 N-m to bend forward. This value remains constant over the 40° range tested. The Gen II-97 design initially requires no additional muscular effort. As the body leans further, the muscular effort required increases to approximately 8 N-m at a 40° forward lean, still less than that needed for the Gen III designs. These results are explained by the torso length of the designs. The Gen III prototypes extend further down the torso. In leaning forward, the user must bend the ballistic material. It may be possible to create a hinge in the ballistic fill in this area to reduce the initial resistance to forward bending while retaining the flat stiffness characteristic of these designs.

4.3 Resistance to Sideways Leaning

Resistance to sideways leaning for the three fragmentation vest designs is shown in Figure 4 and summarized in Table 8.

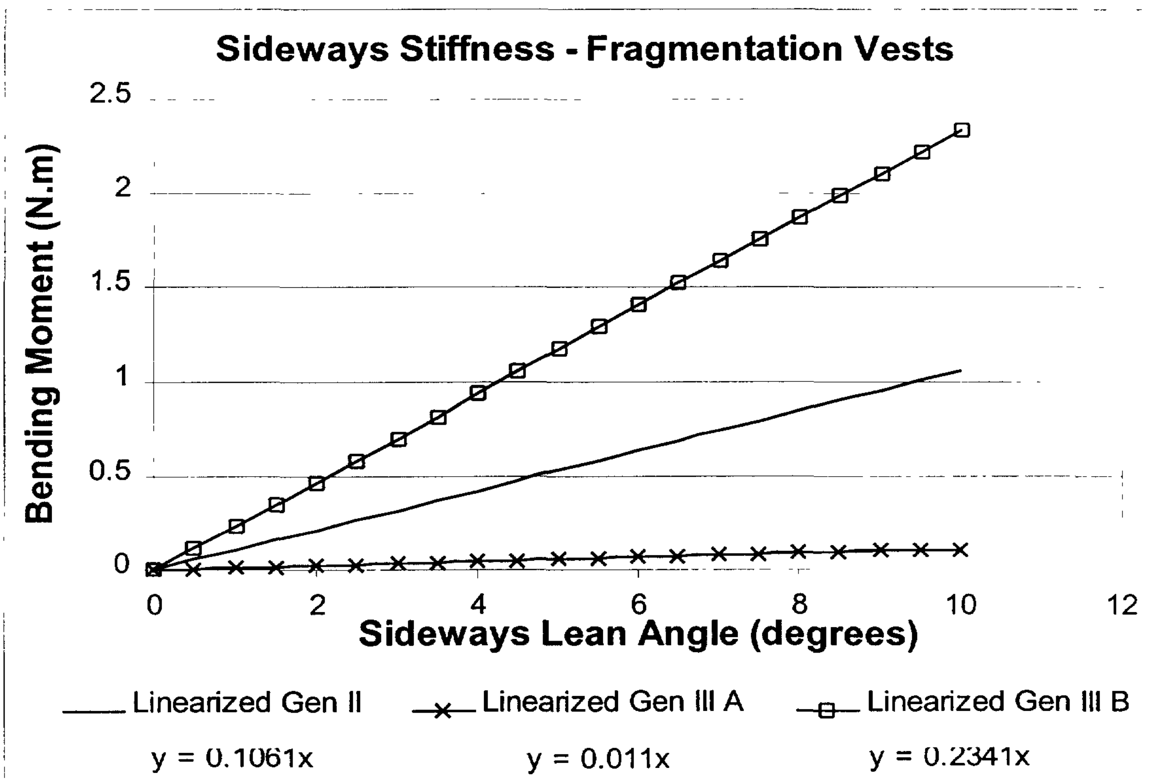

Figure 4. Fragmentation vest resistance to motion during a +/- 10° lateral lean.

Table 8. Summary of sideways bending stiffness and the moment required to initiate bending.

Frag Vest Design	Sideways Bending Stiffness	Initialization Moment
Gen II– 97F	+ 0.11 N-m/degree	- 1.7 N-m
Gen III A	+ 0.01 N-m/degree	- 2.5 N-m
Gen III B	+ 0.23 N-m/degree	- 3.8 N-m

The two sided closure used under the arms in both Gen III A and Gen II 97F designs reduces the effective stiffness of these frag vests. Additionally, the Gen III A design achieves almost no resistance to motion over the 10° range of lateral lean. In comparison, the asymmetrical frontal closure on the Gen III B offers twice the resistance of the existing Gen II 97F. Since this motion is required for simple walking gait, increased resistance is expected to result in a higher energy cost over long duration activities. [6]

5.0 Conclusions and Recommendations

There is sufficient understanding of the effects of high contact pressures and mobility reduction to conclude the following:

Discomfort Issues:

1. The lap joint closure design used on both shoulders of the Gen II-97 and on the left shoulder of the Gen III B design will cause appreciable user discomfort when worn under a loaded tactical assault vest, (TAV).

2. The shoulder regions of the Gen III A design demonstrated an even distribution of pressure at values below the contact pressure threshold limits when worn under a TAV with a 98 N fighting load.

3. The hidden female Fastex® connector located under the front lower pocket of the TAV will be pressed into the hip area by any load carried in this pocket. Presence of a fragmentation vest may not sufficiently shield this area to avoid injury.

4. The elasticity of the mesh that supports pockets on the TAV will tend to allow the top of pockets to rotate away from the body, which will tend to press the inside bottom edge into the body. Understanding this behaviour may prevent future problems due to the pivoting of the loaded pocket.

Resistance to Torso Motion

5. The Gen II -97F had the highest resistance to twisting the torso (rotation about a vertical axis) 0.645 N-m, followed by the Gen III B with 0.473 N-m. The Gen III A offered the least

resistance to twist with 0.319 N-m. As this motion is required for a walking gait, any increased resistance is expected to result in higher energy costs to the user over long duration activities.[6]

6. During lateral bending, the right and left closure design used in both the Gen III A and Gen II 97F designs reduced the effective stiffness of these frag vests. The Gen III A design achieved almost no resistance to motion over the 10° range of lateral lean.

7. The asymmetrical frontal closure on the Gen III B offers twice the resistance to lateral motion compared to the existing Gen II 97F. Since this motion is required for simple walking gait, increased resistance is expected to result in higher energy costs over long duration activities. [6]

8. The longer torso length in the Gen III designs required greater forward bending effort when compared to the shorter Gen II design. If a hinge could be created in the protective material, this initial moment could be reduced.

Recommendations:

1. The Gen IIIA shoulder design should be used to prevent contact pressure injuries.

2. Edges, layers and discontinuities, will cause unacceptable contact pressures when externally loaded. This was shown at the shoulder and on the front of the hip. Combinations of equipment need to be defined and considered at the design stage.

3. Any connectors or other stress raisers, (particularly the connector located under the lower front pocket of the TAV), should be moved from any locations where a pocket may pivot directly on it.

4. The side closure design for the Gen IIIA prototype was superior in reducing the resistance to lateral motion and should be adopted in future designs.

5. The Gen IIIA design was superior in reducing the resistance to motion about a vertical axis, i.e. twisting. It is the preferred design for this feature.

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14 ABSTRACT

(U) The objective of this work was to assess the biomechanical performance of the current issue fragmentation vest, the Gen II 97-F with lap joint closure at both shoulders, the Gen IIIA with a side opening creating a continuous shoulder and the Gen IIIB with an asymmetrical one shoulder closure style
The dynamic behaviour of each design and its' impact on the user (asymmetrical loading, high hip reaction forces, and high contact pressures on the skin) was quantified using the Load Carriage Simulator Designs were assessed for restriction to upper torso mobility using standard testing on the Load Carriage compliance tester As well, the cause of any poor performance was reported Finally, each fragmentation vest design was evaluated for compatibility with the proposed Tactical Assault Vest (TAV)
Results and conclusions fell into two categories, factors related to user discomfort and factors related to user mobility

User Discomfort

- The shoulder lap joint closure on the Gen II-97 and Gen IIIB designs caused pressures expected to induce appreciable user discomfort when worn

under a loaded (98 N) tactical assault vest, (TAV) The shoulder region of the Gen IIIA design demonstrated a smooth acceptable distribution of pressure
• The hidden female Fastex® connector located under the lower front pocket of the TAV caused very high local contact pressures (>89kPa) Elasticity of the mesh on the TAV allowed the top of pockets to rotate away from the body, this pressed the inside bottom edge of pocket contents into the body

Resistance to Torso Motion
• The Gen II -97F had the highest resistance to torso rotation about a vertical axis , followed by the Gen IIIB with 0 473 N-m The Gen IIIA offered the least resistance to twist with 0 319 N-m As this motion, and lateral bending, are required for a walking gait, increased resistance is expected to result in higher energy costs to the user over long duration activities [6]
• During 10• of lateral bending, the side closure design in the Gen IIIA and Gen II 97F reduced the bending moment required with the Gen IIIA having *almost no resistance to lateral motion The lapped front closure on the Gen IIIB had twice the lateral resistance of the Gen II 97F*
• The longer torso length in the Gen III designs required greater forward bending effort compared to the shorter Gen II design If the protective material could be hinged, this moment would be reduced

The Gen IIIA prototype design was found to offer superior performance compared to the current issue fragmentation vest for the following distribution of the TAV load onto the shoulders, reduced resistance to lateral bending and reduced resistance to rotation of the torso about the vertical axis.
Edges, layers and discontinuities will cause unacceptable contact pressures when externally loaded. This was shown at the shoulder and on the front of the hip Combinations of equipment need to be defined and considered at the design stage Connectors or other discontinuities, particularly the connector under the lower front pocket of the TAV, should be moved from locations where a pocket might rest directly on it
The elasticity of the TAV mesh may contribute to user discomfort by allowing the top of loaded pockets to move away from the body, causing the inside lower edge to pivot on the body If this occurs on top of a hard connector, underlying tissue can experience extreme point loading

15 KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Generation III Fragmentation Vest; Fragmentation Vest, Ballistic Vest; Ballistic Protection, Clothe the Soldier, Biomechanical Evaluation, Load *Carriage Simulator; Advanced Personal Load Carriage System; APLCS, Generation II Fragmentation Vest*

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