This page is left blank

This page is left blank

EVALUATION OF ALTERNATIVE METHODS FOR INCREASING TOLERANCE TO +Gz ACCELERATION

PHASE 2

Final Report

DCIEM Contract Number W7711-8-7042/01-SE

DSS File Number 07SE.W7711-8-7042

Principal Investigator

J. D. MacDougall Ph.D.

Department of Physical Education and

Department of Medicine

McMaster University

Hamilton, Ontario L8S 4K1

Scientific Authority

Dr. F. Buick

Biosciences Division

Defence and Civil Institute of

Environmental Medicine

Toronto, Ontario

December 1989

INTRODUCTION

Maintenance of brain level arterial blood pressure and flow is vital while undergoing high and sustained radial headward acceleration (+Gz), which is common in tactical aircraft. Based on the hydrostatic column model, one can estimate that (assuming no reflex cardiovascular adjustments) for each additional +Gz, eye-level systolic pressure is reduced by approximately 22 Torr (DeHart 1985). This means, for example, that at +6Gz, a pilot would need an almost 2 fold increase in heart level blood pressure in order to maintain the same eye-level pressure as at 1 G. It follows that any protective maneuver which results in an elevation of arterial blood pressure should increase tolerance to +Gz stress. Moreover, the maneuver which causes the greatest increase in blood pressure with the minimum of fatigue should be the most effective in situations of sustained +Gz.

In a previous study at +1Gz (see Final Report, DCIEM Contract #W711-6-9281/01 SE, March 1988; and MacDougall et al. 1989a) we found that considerably greater elevations in mean arterial pressure could be gained by performing forceful dynamic contractions of the legs than by performing a forceful Valsalva straining maneuver. In addition, for a given increase in blood pressure, dynamic leg contractions were found to be considerably less fatiguing than the Valsalva maneuver. Based on these findings, the present study was undertaken in order to determine the optimum forceful leg contraction protocol which could assist the anti-G straining maneuver and would be feasible for future testing in a human centrifuge.

The specific purposes of this phase were:

1. **To evaluate the blood pressure response to various intensities of leg press during isometric (muscle length constant), concentric (muscle length decreasing) and eccentric (muscle length increasing) contractions.** Although it is known that skeletal muscle can develop approximately 50% more force when a maximal contraction is performed eccentrically (compared to concentrically) and approximately 20% more force when the contraction is performed isometrically (compared to concentrically), it was not known which type of contraction would result in the greatest elevation of blood pressure.
2. **To evaluate the effectiveness of various isometric contraction/relaxation protocols for increasing and maintaining an elevated blood pressure.** It was anticipated that maintenance of an isometric contraction would impede venous return from the legs and therefore that increases in blood pressure would be reduced over time. We hypothesized that brief relaxation intervals would be effective in generating a "muscle pumping" action to ensure diastolic filling and maintenance of the elevated blood pressure.
3. **To determine the optimum hip and knee joint angle which results in the greatest increase in blood pressure for a given isometric contraction force.** This query resulted from our Phase 1 finding that the blood pressure

response varied throughout different joint angles for the forceful dynamic exercise when lifting a given weight.

4. **To determine whether or not the magnitude of the blood pressure response to forceful contractions of the legs is related to the subject's absolute muscle size and/or strength.** The answer to this question was considered to have relevance in determining the optimum physical training program for aircrew.

METHODS

The present study was conducted in 2 parts. In Part 1, 11 physically active healthy male subjects (age 23, ± 4 yr.) which represented a very wide range in thigh muscle size were recruited. In Part 2, 6 male subjects (21 ± 2 yr.) were recruited. All subjects were informed of the purpose of the study and the possible risks before signing a consent form. Subject characteristics are presented in Table 1.

Arterial blood pressure was measured directly by intra-arterial catheterization. Under local anethesia a 20 gauge catheter was inserted percutaneously into the brachial artery. The catheter was connected to a pressure monitoring kit and Novadome (Medex Inc. MX8004) which was coupled to a pressure transducer (Medex Inc. MX807). The blood pressure signal was amplified by a Gould Universal Amplifier and mean blood pressure (MBP) was derived by integration of the signal using a custom electronic integrator and division by time. The linearity of the blood pressure transducer was

Table 1. Subject characteristics

	Subject	Height (cm)	Weight (kg)	Age (yrs)
Part 1.	ZA	178.5	73.8	19.1
	GC	190.0	120.0	31.7
	JF	167.5	68.8	22.1
	ZH	175.5	79.8	19.0
	RI	176.0	82.8	28.3
	DR	165.0	60.1	19.0
	JK	170.6	68.8	22.2
	BM	178.5	73.4	21.7
	SO	177.8	67.4	24.0
	JS	177.0	85.4	20.6
	RS	190.0	116.0	27.7
	$\bar{x}$	176.9	81.5	23.2
	±SD	7.9	19.5	4.3
Part 2.	RF	177.0	98.6	21.3
	AG	180.0	75.3	24.7
	EK	187.0	86.3	22.0
	MM	179.0	80.8	20.5
	GN	177.5	81.3	20.3
	DP	181.0	72.6	20.0
	$\bar{x}$	180.3	82.5	21.4
	±SD	3.6	9.3	1.6

confirmed throughout a range of 0 to 500 Torr by calibrating the system against a strain gauge reference transducer. In addition, the system was calibrated before each test against a mercury manometer by injecting various pressures between 0 and 300 Torr into the system. The BP integrator was calibrated by inserting 200 Torr static pressure into the system with a syringe and adjusting the gain on the integrator such that one reset cycle was 2 s. This resulted in 400 Torrs per reset cycle. Blood pressure was recorded with the transducer at mid-sternum level. Blood pressure (BP), the integral of blood pressure and intrathoracic pressure (ITP) were recorded continuously on a 6 channel Gould chart recorder (Brush 260) in Parts 1 and 2 of the study. In addition, in Part 2, leg press force of each leg was recorded. Intrathoracic pressure was measured using a MMI gaeltec catheter transducer (Model 16CT/SB). Leg press force was measured at each foot plate by means of strain gauge load cells (DS Europe Model 5460-220) attached to the foot plates of a modified Global leg press machine (Model SR 3221). All analog signals were also digitized, displayed and saved on a Zenith IBM AT compatible computer (Model ZBF-2526-EK). In order to simulate actual flight conditions, subjects sat in an ejection seat from a Canadian Forces Aircraft which was mounted on the modified leg press apparatus. By adjustment of both seat and foot plate positions it was possible to achieve a wide range in hip and knee joint angle starting positions. The direction of the leg press was 90^o to the normal gravitational vector.

In Part 1, subjects performed 10 - 12 RM (the maximum weight that could be lifted for 10 - 12 repetitions) simultaneous (double) leg press exercise on the modified leg press apparatus. Cross-sectional area of the right and left thigh muscle was measured by a computerized digitizer from CT scans of the thigh taken mid-way between the greater trochanter and lateral epicondyle of the femur. (Model 20-30 Ohio-Nuclear). See Figure 1.

In Part 2, data was collected according to 3 separate protocols, performed on separate days (Table 2). With the first protocol, maximum isometric voluntary contractions (MVC) were performed with both legs simultaneously on a modified Global Gym leg press apparatus at 4 different knee joint angles: 75^o, 90^o, 105^o and 120^o. Subjects were then asked to perform a series of isometric contractions at an intensity of 70% MVC at these same joint angles. Contractions were maintained for 30 s. Subjects were provided with real time feedback of leg press force via an oscilloscope to assist them in maintaining the prescribed contraction intensity. Three minute rest periods were provided between trials and the order of the sets was randomized to control for the possible effect of fatigue.

Since it was found that the increase in mean blood pressure was the same at the same relative force for knee joint angles 75^o, 90^o and 105^o despite major differences in absolute force (see results section) it was decided that all subsequent isometric measurements would be conducted at a knee angle of 105^o. For the second protocol, subjects performed isometric MVC's during simultaneous (double) and alternate (single)

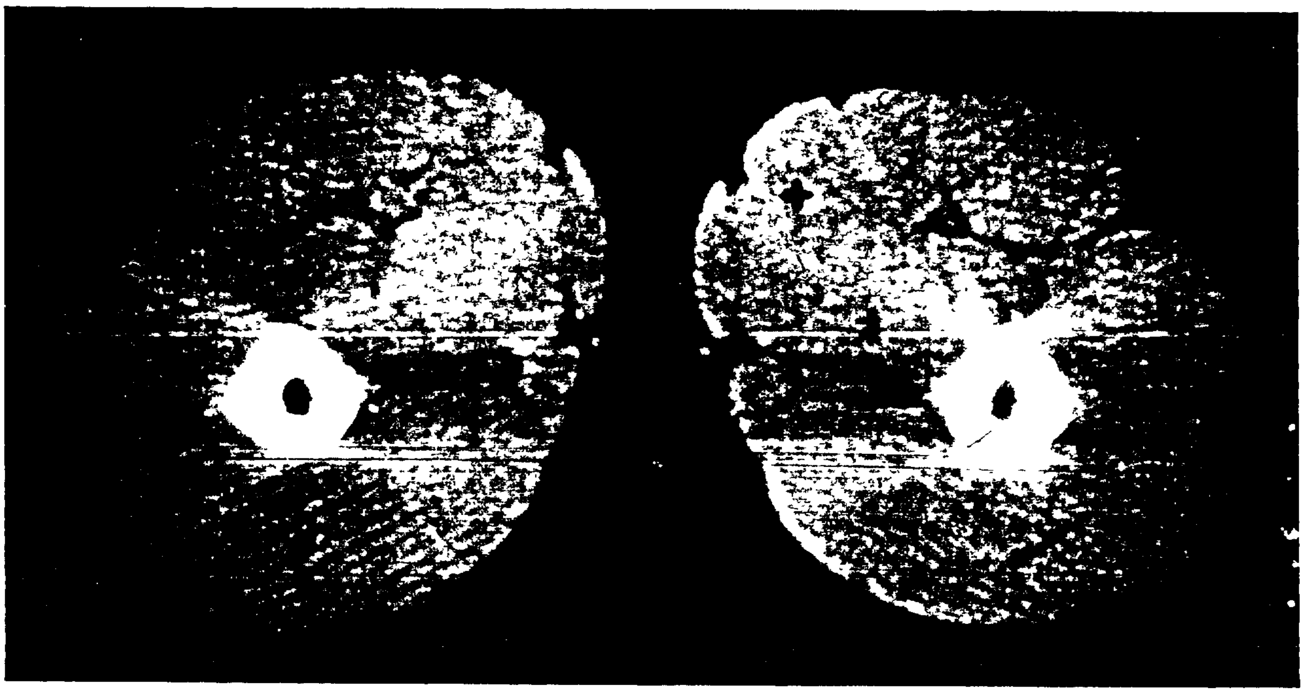

Figure 1

CT scan of upper thighs for determination of muscle cross sectional area.

Table 2. Protocol for Measurements in Part 2.

Protocol	Set	Type of Contraction	Intensity % MVC	Alternate or Simultaneous Leg Press	Contraction Time Sec	Relaxation Time	ITP % max	Knee Angle °
1	1	isometric	70	sim.	30	0	N/A	75
	2	isometric	70	sim.	30	0	N/A	90
	3	isometric	70	sim.	30	0	N/A	105
	4	isometric	70	sim.	30	0	N/A	120
2	1	isometric	90	alt.	5	5	N/A	105
	2	isometric	90	sim.	5	5	N/A	105
	3	isometric	90	sim.	5	2	N/A	105
	4	isometric	70	alt.	5	5	N/A	105
	5	concentric & eccentric	70	sim.	30	0	60	105
3	1	isometric	50	sim.	3	3	N/A	90
	2	isometric	70	sim.	3	3	N/A	90
	3	isometric	87.5	sim.	3	3	N/A	90
	4	concentric	50	sim.	3	3	N/A	90
	5	concentric	70	sim.	3	3	N/A	90
	6	concentric	87.5	sim.	3	3	N/A	90
	7	eccentric	50	sim.	3	3	N/A	90
	8	eccentric	70	sim.	3	3	N/A	90
	9	eccentric	87.5	sim.	3	3	N/A	90

leg press exercise at this knee angle for 30 s. Subsequently, combinations of various intensities and contraction and relaxation durations were performed (Table 2). Simultaneous leg press contractions were performed with 90% MVC for 5 s with 5 s relaxation time between contractions in one set (S9055) and for 5 s with 2 s relaxation in another set (S9052). Alternate leg press contractions were performed for 5 s with 5 s relaxation between contractions with 90% MVC in one set (A9055) and with 70% MVC in another set (A7055). In addition, maximum concentric lift (1 RM) and maximum intrathoracic pressure (determined as that intrathoracic pressure generated by a valsalva maneuver that could be maintained for 5 s) were measured. Valsalva maneuvers were performed by forceful exhalation against a closed glottis. Subjects were asked to maintain a valsalva maneuver at an intensity that would elicit an ITP of 60% of maximum for 30 s while performing simultaneous isometric leg press exercise at 70% MVC (S70ITP). The order of sets was randomized.

For the third protocol, subjects performed isometric, concentric and eccentric simultaneous leg press contractions at a starting knee joint angle of 90^o with 50, 70 and 87.5% MVC for 3 s with 3 s relaxation between contractions. During concentric contractions, only the concentric phase of the repetition was performed by the subjects and the weight was lowered by volunteers using a custom designed extension to the weight stack. Thus, the weight was lifted by the subject during 3 s and lowered by the volunteers for 3 s. Similarly, during the eccentric contractions only the eccentric phase of the repetition was performed by the subject.

In order to minimize the effect of progressive sets and fatigue on the blood pressure response, two steps were taken. First, the order of sets was randomized and second, MBP for every test trial was converted to a value representing the change in MBP from the pre-trial resting measurement. This value is referred to as delta mean blood pressure (ΔMBP). Intrathoracic pressure is reported as the average pressure (integrated over time) over the 30 s period (mean ITP) and thus also includes the decreases in pressure which occur when subjects inspire. In addition the highest ITP recorded over the 30 s period (peak ITP) and the mean of all ITP peaks (mean peak ITP) were calculated. Data in Part 1 were analyzed using Pearson's Correlation Coefficient. Data in protocols 1 and 2 of Part 2, were analyzed using a one factor analysis of variance with repeated measures. Data collected in protocol 3 were analyzed using a two factor (contraction type and intensity) analysis of variance with repeated measures on both factors. In protocol 3, one subject (because of an injury unrelated to the project) was unable to perform a concentric contraction with 87.5% MVC and therefore his missing data was substituted with the mean of the other 5 subjects. Tukey's post hoc test was used to determine significant differences among mean values when there was a significant interaction.

RESULTS

The Effects of Muscle Size and Strength

The effects of muscle size and strength on the magnitude of the blood pressure response when performing 10 - 12 RM leg press exercise are illustrated in Figures 2A and 2B. It can be seen that although individual differences exist, the peak systolic and diastolic pressures reached are independent of muscle size (Figure 2A) or absolute weight lifted (Figure 2B) despite a very wide range in size and strength. The mean peak systolic pressure for the 11 subjects was 343±38 Torr and the mean peak diastolic pressure was 235±34 Torr during this exercise.

The Effects of Knee Joint Angle

The effects of different knee joint angles on strength and blood pressure response are summarized in Table 3. As expected, knee joint angle had a major effect on the force which subjects could exert with a maximum isometric contraction. At knee joint angles of 75, 90, 105 and 120°, maximum forces were 187 ± 9, 221 ± 13, 310 ± 20 and 454 ± 15 kg respectively. In spite of these differences in force, the blood pressure response (MBP and ΔMBP) was the same for joint angles 75, 90 and 105° when subjects performed contractions at 70% MVC. It was significantly less at a joint angle of 120° even though the force exerted at this angle was greatest. Peak systolic and diastolic blood pressures

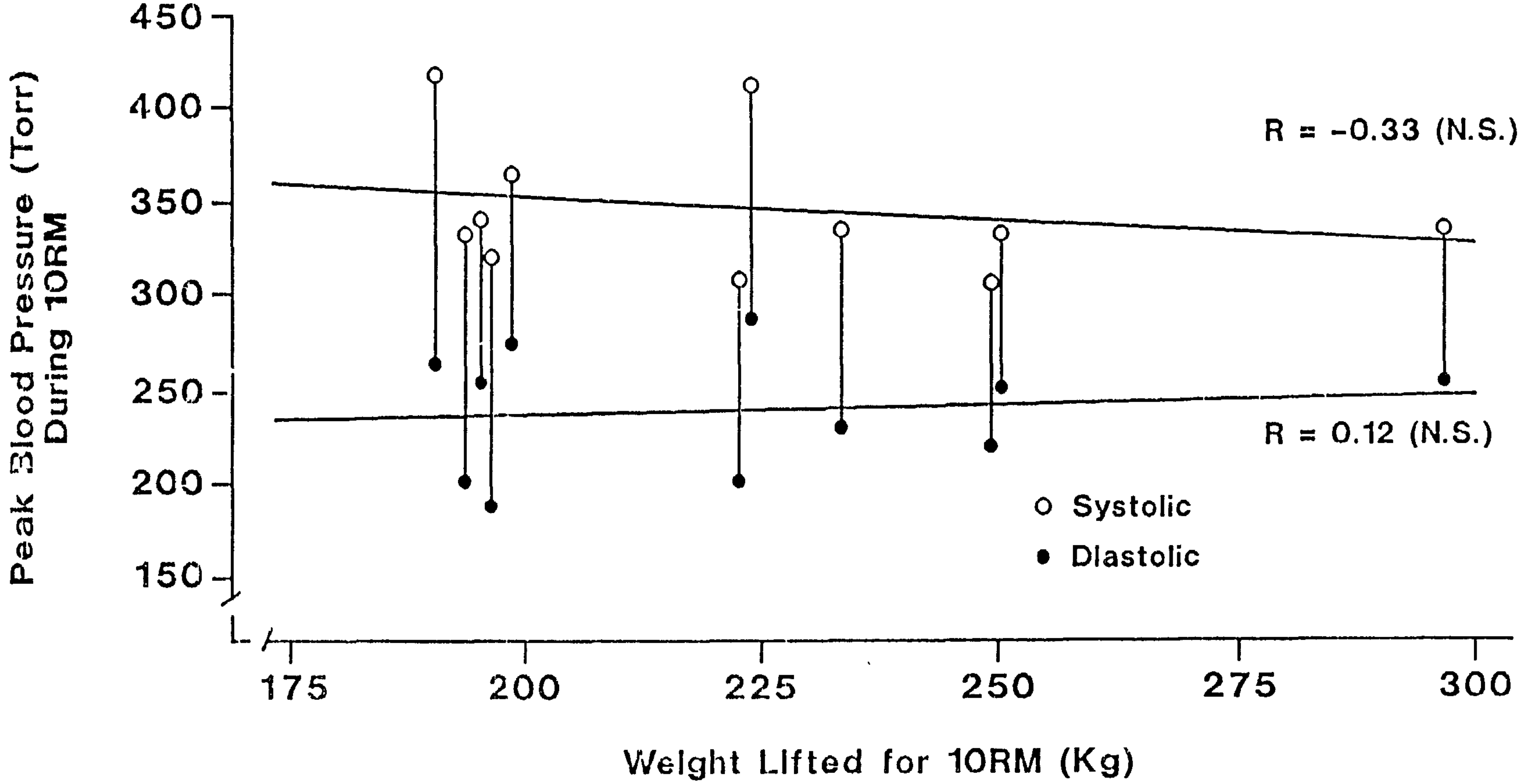

Figure 2A

Relationship between peak systolic and diastolic blood pressure and absolute weight lifted for a 10 RM (N=11). Regression lines for systolic and diastolic pressures. Relationship is non-significant.

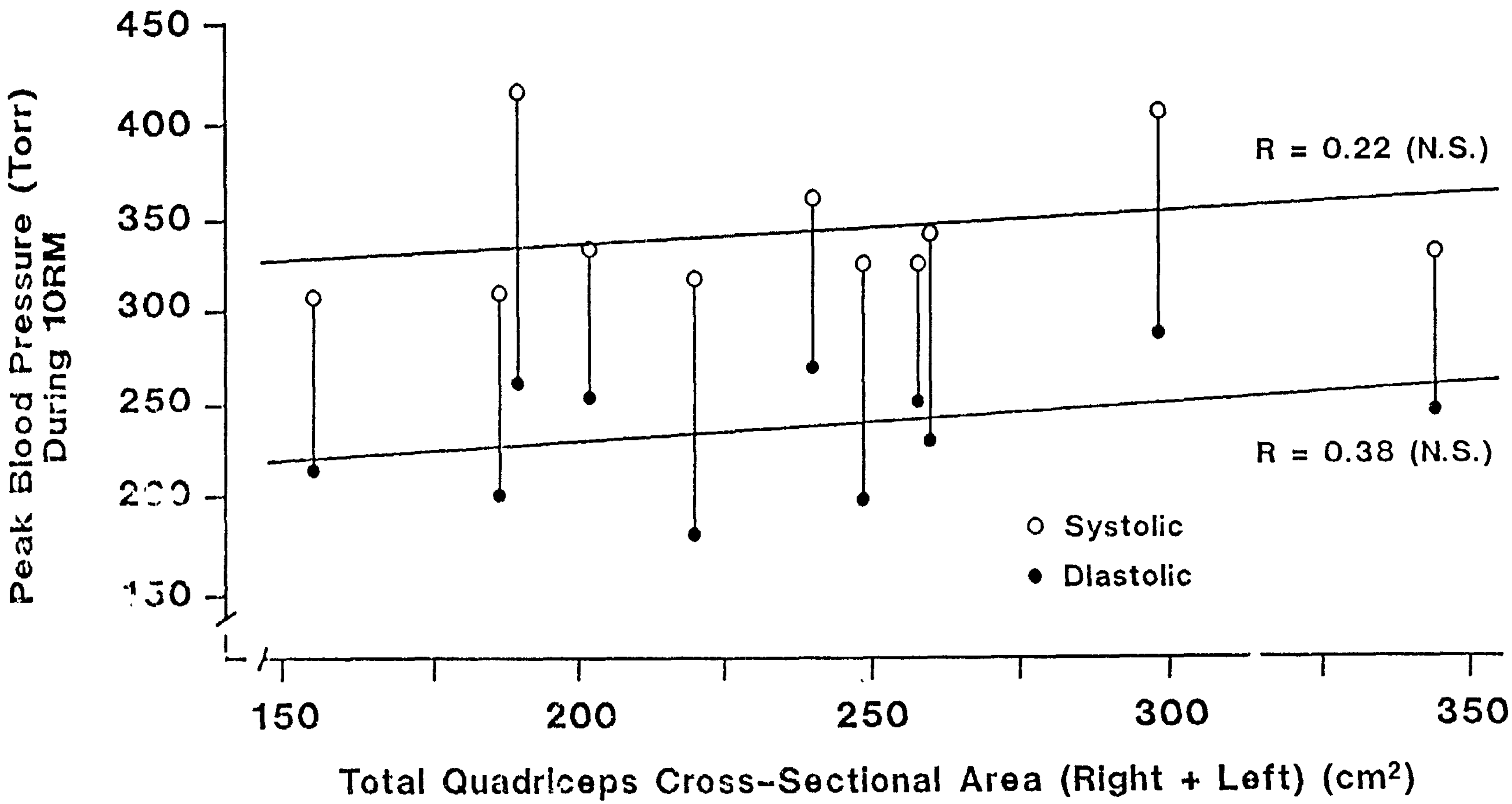

Figure 2B

Relationship between peak systolic blood pressure during a 10 RM and quadriceps cross sectional area (N=11). Relationship is non-significant.

were not affected by changes in knee joint angle nor was peak intrathoracic pressure (ITP).

The Effects of Double vs. Alternate Leg Isometric Contractions

The effects of performing isometric simultaneous (double leg) contractions vs single leg alternating contractions are summarized in Table 4(a). At 90% MVC the mean blood pressure response was 43% greater ($p<0.01$) when 5 s sets were performed with alternate legs (A9055) than when they were performed with both legs simultaneously for 5 s with a 5 s rest (S9055). When simultaneous leg presses were performed for 5 s with 2 s rest (S9052) the response was the same as for alternating legs (A9055). Simultaneous leg contractions at 70% MVC maintained for 30 s in combination with a forced valsalva maneuver at 60% maximum intrathoracic pressure (S70 ITP) resulted in a greater ΔMBP ($p<0.05$) than the S9055, S9052 and A7055 condition but not A9055.

Table 4(b) illustrates the differences in ITP and BP which occurred when subjects performed a continuous 30 s isometric contraction at 70% MVC with a minimal Valsalva (i.e., their normal, involuntary Valsalva) compared to the same procedure with a 60% maximal Valsalva super imposed.

The Effects of Isometric vs Concentric and Eccentric Contractions

Isometric contractions at 87.5% MVC, held for 3 s and released for 3 s, resulted in a higher ΔMBP ($p<0.01$) and MBP ($p<.05$) response than either concentric or eccentric

Table 3. Blood pressure and ITP response to isometric simultaneous leg press exercise with 70% MVC at four different knee joint angles.

	Knee Joint Angle			
	75°	90°	105°	120°
MBP (Torr)	160.3 ± 3.7	157.4 ± 5.6	163.8 ± 4.6	145.4 ± 4.6*
ΔMBP (Torr)	56.8 ± 2.9	55.2 ± 7.5	60.2 ± 6.6	42.6 ± 3.5*
Peak Systolic BP (Torr)	251.5 ± 15.1	251.5 ± 16.6	263.6 ± 20.2	235.0 ± 14.4
Peak Diastolic BP (Torr)	155.7 ± 14.52	157.5 ± 29.62	173.9 ± 32.92	138.4 ± 23.4
Peak ITP (Torr)	51.7 ± 15.2	34.3 ± 17.8	30.4 ± 15.3	32.3 ± 6.8
Mean Peak ITP (Torr)	27.7 ± 10.5	24.5 ± 13.3	14.8 ± 8.0	17.1 ± 4.5
Mean Resistance at 70% MVC, (kg)	130.8 ± 9.3	155.0 ± 12.9	216.7 ± 20.3!	318.3 ± 15.1**

Values are mean and SE

*indicates significant difference from 105° ($p<.05$)
**indicates significant difference from 105, 90 and 75° ($p<.01$)
!indicates significant difference from 90 and 75° ($p<.01$)

Table 4(a). Blood pressure and intrathoracic pressure response to isometric simultaneous and alternate leg press exercise with different intensities. Blood pressure (ΔMBP and MBP) has been averaged over 30 s.

		Condition				
		A9055	A7055	S9055	S9052	S70ITP
ΔMBP (Torr)	x	61.2!!	41.1	34.9	48.0	79.7!
	SE	7.4	5.9	6.5	2.1	9.1
MBP (Torr)	x	149.1	138.8	132.1	143.0	179.6**
	SE	3.3	7.4	5.6	3.8	7.6
Peak Systolic	x	267.0	250.0	261.3	268.5	304.7*
BP (Torr)	SE	7.4	21.5	8.2	11.2	17.0
Peak Diastolic	x	161.8	147.9	175.6	185.3	196.8*
BP (Torr)	SE	12.5	17.3	8.7	7.9	12.4

*indicates significant difference from A7055 ($p<.05$).
**indicates significant difference from all other conditions ($p<.01$).
!indicates significant difference from S9052, S9055, A7055 ($p<.01$).
!!indicates significant difference from S9055 ($p<.01$).

Table 4(b). Blood pressure response to a combined Valsalva maneuver and a 70% MVC leg press. Data are compiled from Table 3 (105° joint angle) and Table 4(a) (S70 ITP condition). Blood pressure and intrathoracic pressure have been averaged over the 30 s period.

Condition		Leg press with normal (involuntary) Valsalva	Leg press with additional Valsalva (60% max)	Δ
Mean ITP	x	6.8	63.3**	57.5
(Torr)	SE	12.8	14.4	
MBP	x	163.6	179.6**	16.0
(Torr)	SE	11.1	18.5	
ΔMBP	x	60.2	79.7**	19.5
(Torr)	SE	16.3	22.2	

**$p<.01$

contractions at the same relative intensity (Table 5). Furthermore, isometric contractions at 70% MVC produced a higher MBP ($p>0.05$) than did the other 2 exercise modes. No differences were evident between the 3 different types of contraction at 50% MVC. Also there was no significant difference in the peak systolic, diastolic or ITP response to the 3 different types of contraction for a given intensity.

DISCUSSION

Muscle Size and Strength

Our data reaffirm our previous findings of extreme increases in systolic and diastolic blood pressure when healthy young subjects perform maximal weight lifting (MacDougall et al. 1985). The magnitude of this pressure increase was, however, similar for all subjects and was not affected by individual differences in muscle size or strength. We conclude therefore that the increase in BP is determined by the relative effort involved and not the absolute force of contraction (i.e., it is the same for small subjects as for larger, stronger subjects while performing a 10 - 12 RM).

It is thus possible that subjecting Canadian Forces personnel to a heavy resistance training program which is designed to increase muscle strength (or size) may not result in a further elevation in the BP response during forceful contractions, however we recognize that a true longitudinal training study would be necessary in order to resolve this issue. Moreover it is possible that such training might also prove beneficial by improving an

Table 5. Blood pressure and intrathoracic pressure response to three contraction types with three exercise intensities.

	Contraction Type	Contraction Intensity (% MVC) 50	70	87.5
ΔMBP (Torr)	Concentric	8.9 ± 3.0	17.9 ± 4.7	18.5 ± 3.2
	Isometric	15.9 ± 1.8	26.5 ± 7.1	40.5 ± 5.1*
	Eccentric	11.3 ± 1.1	18.6 ± 2.2	15.5 ± 2.0
MBP (Torr)	Concentric	107.9 ± 3.9	120.0 ± 4.1	122.0 ± 3.4
	Isometric	113.0 ± 4.0	129.6 ± 3.3**	138.3 ± 4.7**
	Eccentric	109.1 ± 4.3	116.4 ± 3.5	119.0 ± 3.7
Peak Systolic BP (Torr)	Concentric	200.2 ± 8.7	240.6 ± 12.8	263.0 ± 7.8
	Isometric	200.1 ± 9.4	240.6 ± 11.9	282.2 ± 14.4
	Eccentric	197.4 ± 7.7	221.1 ± 6.5	239.4 ± 7.9
Peak Diastolic BP (Torr)	Concentric	105.2 ± 7.7	136.0 ± 16.5	142.2 ± 5.6
	Isometric	112.4 ± 6.9	154.3 ± 8.9	181.3 ± 9.8
	Eccentric	108.5 ± 5.7	114.6 ± 10.3	144.0 ± 13.6
Peak ITP (Torr)	Concentric	17.4 ± 3.8	49.4 ± 12.6	51.1 ± 7.5
	Isometric	20.2 ± 7.6	41.4 ± 7.9	75.4 ± 8.2
	Eccentric	22.9 ± 9.2	44.8 ± 9.4	65.8 ± 7.5
Mean Peak ITP (Torr)	Concentric	13.2 ± 2.8	34.0 ± 9.6	40.8 ± 5.3
	Isometric	16.4 ± 6.4	35.1 ± 5.3	62.9 ± 7.7
	Eccentric	19.3 ± 7.0	31.8 ± 6.6	53.1 ± 6.7

Values are mean and SE

*indicates significant difference from concentric and eccentric sets with same intensity ($p<.01$).
**same as above ($p<.05$).

individual's resistance to fatigue and thus improve his performance in situations requiring repeated demands of high +Gz tolerance.

Joint Angle

As above, it is also apparent that the magnitude of the BP response during isometric contractions is related to the relative intensity and is independent of knee joint angle despite the wide range in absolute force production which occurs at different knee joint angles. Knee joint angle for an isometric leg press device could thus be any angle between 75 and 105^o and produce the same elevation in BP provided that the effort is the same. A knee joint angle of 120^o or greater is not as effective because in our system slight movement (bending of the ejection seat and its support as well as "play" within the human skeletal-connective tissue system) permitted some of the stronger subjects to "lock out" their knees at this larger joint angle.

Double vs. Alternate Leg Contractions

It was hypothesized that the inclusion of brief relaxation periods with the isometric contractions would permit the "muscle pump" to augment venous return and thus result in an elevated BP response. Inspection of the data in Tables 3 and 4, however, indicate that ΔMBP and MBD are higher when a 70% MVC isometric contraction is held continuously for 30 s than when a 90% MVC contraction is performed with either a 5 s contraction phase and a 5 s relaxation phase (S9055) or a 5 s contraction phase and a 2 s relaxation phase (S9052). It is also evident that the MBP at 90% MVC is higher when the relaxation period is 2 s instead of 5 s. Since BP decreases rapidly during the relaxation period, the duration of this phase is obviously very critical. It is possible that, had the relaxation periods been of shorter duration (e.g., 1 s or less), the procedure may have been more effective.

Alternating single leg contractions at 70% MVC (A7055 in Table 4) was not as effective as maintaining a simultaneous double leg contraction continuously at 70% MVC (Table 3). Apparently with this procedure any benefits in venous return were offset by the fact that the active muscle mass was reduced by 50%.

The contribution of the Valsalva maneuver (increased ITP) to the BP response is illustrated in Tables 4(a) and 4(b). It is evident that, in order to maintain a given isometric contraction force, subjects involuntarily perform a certain intensity of a Valsalva maneuver. The greater the force of contraction - the greater is the intensity of the Valsalva maneuver (ITP). When subjects superimpose an even more forceful voluntary Valsalva maneuver (S70 ITP) on a held isometric contraction, this results in the highest elevation in ΔMBP. Under such circumstances, however, the relationship between the increase in ITP and the increase in MBP is not linear. For example, ITP with the addition of the forced Valsalva was approximately 58 Ton higher than with the normal degree of Valsalva. The difference in ΔMBP was 19.5 Ton and MBP was 16 Ton (Table 4(b)).

Of the protocols investigated, the most effective method for increasing ΔMBP over 30 s appears therefore to be a combination of a continuous forceful double leg isometric contraction and a voluntary forceful Valsalva maneuver. The magnitude of the increase in ΔMBP is directly related to the intensity of these 2 processes. Whether or not the inclusion of very brief (>1 s) relaxation periods with the isometric contraction (e.g., every 5 s) will augment this response cannot be determined from these data.

Isometric vs. Concentric vs. Eccentric Contractions

Because of the greater absolute force which is developed with eccentric contractions it was hypothesized that this would also result in the greatest increase in BP. This was not the case, and it was found that the isometric mode of exercise resulted in the greatest increase in ΔMBP and MBP. Again, as above, the addition of brief relaxation periods for the augmentation of venous return was not as effective as continuous held isometric contractions (Tables 3, 4 and 5).

CONCLUSIONS

1. The most effective mode of leg muscle contraction for elevating mean blood pressure over a period of 30 s is an isometric contraction.
2. Since it is the relative intensity of the exercise which determines the magnitude of the response, knee joint angle can vary between 75 and 105^o without affecting it.

3. Simultaneous (i.e., double leg) contractions are superior to alternating leg contractions (i.e., while one leg contracts the other relaxes) because of the larger muscle mass which is activated.
4. A continuous isometric contraction held for 30 s is superior to a protocol where contractions are alternated with a relaxation phase (e.g., 5 s contraction and 2 s relaxation), however the effect of a shorter relaxation phase (e.g., <1 s) remains unknown.
5. The magnitude of the blood pressure response with isometric exercise can be further increased by superimposing a voluntary Valsalva straining maneuver over and above that which occurs naturally.
6. The magnitude of the response is independent of individual differences in absolute muscle strength and/or size and is directly related to the relative intensity or degree of effort.

REFERENCES

DeHart, R.L. Fundamentals of Aerospace Medicine. Lea and Febiger, Philadelphia, 1985.

MacDougall, J.D., R.S. McKelvie, D.E. Moroz, J.S. Moroz and F. Buick. The effect of forceful dynamic leg contractions on blood pressure: Implications for improving tolerance to +Gz. Abstract in Aviation, Space and Environ. Med. A36, 211, May 1989a.

MacDougall, J.D., R.S. McKelvie, D.E. Moroz, D.G. Sale and N. McCartney. Effects of the Valsalva maneuver, joint angle, and muscle size and strength on the blood pressure response to weightlifting. Abstract in Med. Sci. Sports and Ex. 21:52, 1989b.

MacDougall, J.D., D. Tuxen, D.G. Sale, J.S. Moroz and J.R. Sutton. Arterial blood pressure response to heavy resistance exercise J. Appl. Physiol. 58:785-790, 1985.

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.) Dr. J.D. MacDougall, Department of Physical Education, McMaster University, 1280 Main St. W., Hamilton, Ontario Canada, L8S 4K1	2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable) UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

Evaluation of alternative methods for increasing tolerance to +Gz acceleration - Phase II (U)

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

MacDougall, Dr. J.D.

5. DATE OF PUBLICATION (month and year of publication of document) December 1989	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 23	6b. NO. OF REFS (total cited in document) 4

6. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

final contract report

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Ave., W., P.O. Box 2000, Downsview, Ontario, Canada, M3M 3B9

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) ________	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written) DCIEM Contract No. W7711-8-7042
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) -------	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor) ------

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(XX) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
( ) Distribution limited to government departments and agencies; further distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availabilty (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

DCD03 2/06/87

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both offical languages unless the text is bilingual).

(U) Unconsciousness can occur during exposure to sustained, headward radial acceleration (G) due to hypotension at head level, and, methods of improving G tolerance of pilots of high performance aircraft are required. The aim of these experiments at 1 G was to determine an alternate protocol for forceful leg contractions that could assist the standard anti-G straining maneuver to increase blood pressure. Using an exercise of hip and knee extension in the sitting position, it was found that: (i) isometric, muscular contractions were more effective at increasing mean arterial blood pressure than concentric or eccentric contractions; (ii) the relative intensity of the isometric contraction determined the magnitude of the blood pressure increase throughout a knee joint angle range of 75 to 105 degrees; (iii) simultaneous, double leg contractions produced greater blood pressure increases than alternating, single leg contractions; (iv) a continuous 30 sec isometric contraction was superior to repeated 5 sec contractions followed by either 5 or 2 sec relaxation periods; (v) the increase in blood pressure was independent of individual differences in absolute quadriceps muscle strength and/or muscle cross-sectional area, and, was directly related to the relative intensity of contraction effort.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

+Gz tolerance
anti-g protection
anti-g straining maneuver

90-01760
#64027

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM