Effects of Repeated +Gz Exposure on Subjective and Objective Measures of Relaxed +Gz Tolerance

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Disclosure

I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use in my presentation.
Introduction

- Fast-jet flight manoeuvres expose aircrew to high levels of head-to-foot (+Gz) acceleration:
  - Reduced head-level blood pressure;
  - Triggering of reflex cardiovascular responses (↑ heart rate & vasoconstriction).

- Mechanisms of blood pressure (BP) and heart rate (HR) control adapt to regular +Gz exposure (Convertino, 2001; Newman et al. 1998):
  - Improved response to (1 G) orthostatic challenges;
  - But, limited evidence that changes actually affect tolerance of increased +Gz.

- Current trend towards greater ground-based training with simulators:
  - Might ↓ exposure frequency attenuate the adaptation associated with +Gz exposure?
Purpose

Investigate the effects of repeated +Gz exposure on relaxed +Gz tolerance (RGT)

• Two frequencies of exposure: 4/wk vs. 2/wk
• Measures of RGT during a gradual onset run (GOR) on a centrifuge
• Laboratory-based (+1 Gz) tests of cardiovascular response to an orthostatic challenge.
Methods
Methods: Subjects & Study Design

- Ten male, experienced centrifuge subjects (28 ± 5 yr; 83.9 ± 11.1 kg)
- Two, 5 week experimental conditions, with a cross-over design
  - +Gz exposure 2 or 4 times per week for 3 weeks (2/wk vs. 4/wk)
- Before and after both conditions:
  - Measurement of RGT on the centrifuge;
  - +1 Gz laboratory tests of cardiovascular function.

RGT = Relaxed +Gz Tolerance
LAB = +1 Gz laboratory tests
Wash-out = no exposure to sustained +Gz
Methods: +Gz Exposures

- Each exposure consisted of 4 simulated air combat manoeuvres (SACM)
- four cycles of 15 s at +5 Gz followed by 5 s at +7 Gz (1.0 G·s⁻¹ on/offset rate)
- muscle tensing and the anti-G straining manoeuvre (AGSM) to maintain clear vision

- Proceeded by 3 GORs for measurement of RGT
Methods: RGT and +1 Gz laboratory tests

- Relaxed +Gz tolerance:
  - Two measurements (separate days) using 3 GORs (0.1 G·sec\(^{-1}\)) separated by 2 min;
  - Subjects terminated run at 60° peripheral light loss;
  - 1\(^{st}\) GOR of each session discarded: RGT = average of remaining 4 runs;
    - RGT throughout exposure period = average of Runs 2 and 3 on each day only.

- +1Gz laboratory tests:
  - Rapid (~4 sec) head-up tilt (HUT) to 75° for 4 min;
  - Incremental HUT (15° every 2 min up to 75°) (Bizoni et al. 2001).

- The mean (range) length of time between laboratory tests and +Gz exposure was:
  - 4/wk: 5 (3–6) days; 2/wk: 5 (3–7) days.

- Data analysed using a linear mixed model (LMM):
  - Factors of Time (Pre- vs. Post-exposure) and Exposure Frequency (2/wk vs. 4/wk).
Results
Results: Basal Physiology

- No change in resting heart rate (HRrest).
- Mean arterial pressure (MAP) was lower with +Gz exposure (92 ± 9 vs 96 ± 8 mmHg), but there was no effect of exposure frequency.

** LMM Main effect of Time (P < 0.01)
Results: RGT during Repeated +Gz Exposure

- No effect of +Gz exposure on RGT.
- RGT measured *throughout* exposure period also unaffected by +Gz exposure.

![Graph showing RGT (+Gz) for 4/wk and 2/wk exposure over weeks 1 to 3.](image)
Results: Objective measures of RGT

- Tendency for maximum HR ($HR_{\text{max}}$) to decrease with +Gz exposure ($P = 0.074$).
- The ↑ in HR ($\Delta HR$) and ↓ in systolic BP ($\Delta SBP$) were attenuated by +Gz exposure.

** LMM Main effect of $Time$ ($P < 0.01$)

* LMM Main effect of $Time$ ($P < 0.05$)

** LMM Main effect of $Time$ ($P < 0.01$)
Results: Head-up tilt

- ↑ in MAP in the first 10 s of rapid HUT was greater with +Gz exposure.
- ↑ in diastolic BP (ΔDBP) during incremental HUT was greater with +Gz exposure.

* LMM Main effect of Time (P < 0.05)
Effect of Cumulative +Gz Exposure

- Compared with Phase 1:
- ΔSBP during GOR, and ΔDBP during incremental HUT, were affected by +Gz exposure, but reversed during ‘wash-out’;
- Only $HR_{max}$ was lower at Phases 3, 4 and 6.

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 6</th>
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<tbody>
<tr>
<td><strong>GOR</strong></td>
<td></td>
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<tr>
<td>$RGT_{(+Gz)}$</td>
<td>3.97 ± 0.62</td>
<td>3.90 ± 0.61</td>
<td>3.80 ± 0.63</td>
<td>3.94 ± 0.71</td>
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<tr>
<td>$HR_{rest}$ (bpm)</td>
<td>70 ± 7</td>
<td>64 ± 8</td>
<td>63 ± 8</td>
<td>65 ± 11</td>
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<tr>
<td>$HR_{max}$ (bpm)</td>
<td>103 ± 7</td>
<td>91 ± 8*</td>
<td>90 ± 9*</td>
<td>93 ± 12*</td>
</tr>
<tr>
<td>ΔHR (bpm/+Gz)</td>
<td>11 ± 3</td>
<td>10 ± 3</td>
<td>10 ± 3</td>
<td>9 ± 2</td>
</tr>
<tr>
<td>ΔSBP (mmHg/+Gz)</td>
<td>-15 ± 5</td>
<td>-11 ± 2*</td>
<td>-14 ± 3</td>
<td>-11 ± 3*</td>
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<tr>
<td><strong>Laboratory</strong></td>
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<td>ΔDBP$_{I-HUT}$ (%)</td>
<td>27 ± 6</td>
<td>50 ± 20*</td>
<td>39 ± 11</td>
<td>48 ± 19**</td>
</tr>
<tr>
<td>ΔMAP$_{R-HUT}$ (mmHg)</td>
<td>8 ± 4</td>
<td>12 ± 5</td>
<td>9 ± 8</td>
<td>13 ± 8</td>
</tr>
</tbody>
</table>

* Different ($P < 0.05$) from Phase 1
Discussion
Discussion

• Greater ↑ in BP during HUT with +Gz exposure consistent with previous studies:
  
  • 10 sec time frame of rapid HUT includes only partial vasoconstrictor response;
  • Greater ↑ in DBP with incremental HUT reflects exaggerated peripheral resistance response.

• ↓ basal BP with +Gz exposure has been reported previously (Stenger et al. 2007):
  
  • Might offset improvements in BP response to orthostatic stress;
  • No reported relationships between basal parameters and +Gz tolerance (Webb et al. 1991).

• Factors (i.e. G levels, exposure duration and frequency) that increase +Gz tolerance to hypergravity remain largely unknown:
  
  • ↑ in tolerance might have gone undetected by the methodology (RGT during a GOR);
  • ‘Acute’ adaptation to successive +Gz exposures with short breaks (Lalande & Buick, 2009)
    • Similar profiles could be used to investigate the effects of chronic +Gz exposure.
Discussion: Limitations

- RGT during GOR only measurement of +Gz tolerance:
- Other tests (*i.e.* rapid onset run, +Gz endurance) might show different effects;
- GOR is reliable method of measuring tolerance ([Lythgoe et al., 2012](#));
- Relaxed separates adaptation from ‘training’ (*↑* experience with AGSM / protective clothing).

- Delay of 3-7 days between +Gz exposure and post-exposure tests:
  - Might have attenuated measured changes in laboratory tests;
  - Not so for RGT as consistent and unchanged throughout study.

- Carry-over effects with cross-over study design and only 3 week ‘lay-off’ period?
  - Loss of G endurance associated with 14 days of ‘lay-off’ ([Morgan et al. 1994](#));
  - $HR_{max}$ during GOR different from Phase 1 at both Phase 3 and 4 (*i.e.* after the wash-out).
Conclusion

• Twice or four times weekly exposure to +Gz for 3 weeks is associated with:
  • a greater increase in BP during HUT;
  • smaller changes in HR and SBP in response to +Gz exposure.

• Changes suggest adaptation that favours resistance to orthostatic stress:
  • However, no effect on subjective RGT as measured during a GOR.
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