

Human Performance & Limitations · Module F — The Forces

The Deceived Pilot

Chapter 15 — Acceleration and the pilot's body: the effects of increased "G", the cascade from grey-out to G-LOC, the 1.41 G reference at 45° of bank, the factors that erode G-tolerance, and negative G with red-out.

BOOK

Human Performance & Limitations

AUTHOR

Ghost Aviator

EXAM

DGCA CPL / ATPL — HPL

CHAPTER

15 of 26 · Module F

In this chapter

1. [Acceleration and "G" Forces — Introduction](#)
2. [Effects of Increased "G" Manoeuvres](#)
3. [1.41 G at 45° — the Reference Number](#)
4. [Factors Adversely Affecting G-Tolerance](#)
5. [Negative G & Red-out](#)



Plate 15.0 — Under high G the body fights its own blood. Vision goes before consciousness — a warning measured in fractions of a second.

§ 61

Acceleration and "G" Forces — Introduction

DGCA-QUOTED — DEFINITION OF 1 G

Flying can expose the human body to conditions for which it is not naturally suited. On the ground, the body is subject to **normal gravitational acceleration: "1G"**. This is **32 ft/sec² or 9.81 m/sec²**. The reaction of the earth's surface to this acceleration **gives us the sensation we call "weight"**.

A pilot will experience 1 G in straight and level flight.

61.1 Load Factor at Bank Angles

DGCA-QUOTED — LOAD-FACTOR NUMBERS (MEMORISE)

- At **60° of bank** a pilot is subject to an acceleration of **2 G** acting vertically through his seat. His weight will also **increase by a factor of 2**. This is called the **LOAD FACTOR**.
- In a **70° level turn**, the load factor increases to **3**.

1 G Straight & level flight (32 ft/s² · 9.81 m/s²)

2 G 60° level bank turn

Join live classes for guided practice and doubt clearing.

DGCA-QUOTED — AEROBATIC CERTIFICATION

A typical **light aircraft cleared for aerobatics** would be **stressed to withstand positive load factors of up to** 6

61.2 Counter-measures against adverse G-effects

DGCA-QUOTED

The **adverse effects of increased "G"** can be delayed or relieved by:

- **Tensing the thigh and stomach**, and
- **Easing off the backward pressure on the control column.**

PHYSIOLOGICAL BACKGROUND

Under high positive G, blood pools in the lower body — **cerebral blood pressure drops**. Early symptoms are **greyout** (loss of peripheral vision), then **blackout** (loss of central vision), then **G-LOC** (G-induced Loss of Consciousness). Tensing the lower body's muscles (the "AGSM" — Anti-G Straining Manoeuvre) raises arterial pressure and forces blood back up to the brain. Easing off the control column reduces the G being demanded.

(More detail in continuation of the chapter.)

§ 62

Effects of Increased "G" Manoeuvres

DGCA-QUOTED — THE SIX EFFECTS (MEMORISE THE ORDER)

During increased "G" manoeuvres the pilot will feel the following effects:

1. **Increase in body weight.**
2. **Mobility is impaired.**
3. **Internal organs displaced.**
4. **Onset of tunnel vision.**
5. **Grey out.**
6. **Possible blackout.**

62.1 The Cascade — From Heaviness to Blackout

- 1 Body weight ↑
- 2 Mobility impaired
- 3 Organs displaced
- 4 Tunnel vision
- 5 Grey-out
- 6 Blackout

Join live classes for guided practice and doubt clearing.

WHY EACH EFFECT HAPPENS IN THIS ORDER — PHYSIOLOGICAL CONTEXT

- **Effects 1–3 (heaviness, immobility, organ displacement)** are *mechanical*: with apparent weight multiplied by the load factor, limbs become difficult to lift, the head is forced down/sideways, and abdominal organs sag against the diaphragm.
- **Effects 4–6 (tunnel → grey → black)** are *cerebrovascular*: high positive G pulls blood downward, away from the head. Retinal arterial pressure falls first (cones in the fovea drain → tunnel vision = peripheral vision fails first), then central vision goes (grey-out), then cerebral perfusion fails (blackout / G-LOC).
- The ORDER of the six effects is the standard DGCA exam point — they happen in **this sequence as G increases**.

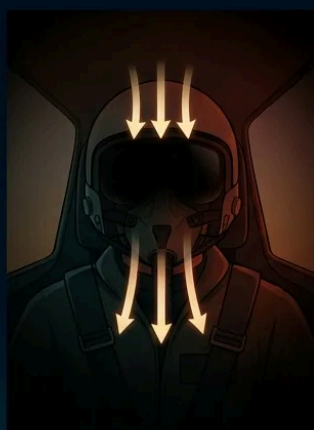
POSITIVE G — GREY-OUT TO G-LOC



CLEAR VISION



GREY-OUT —
tunnel vision,
colour fades



BLACK-OUT —
vision lost,
still conscious



G-LOC —
G-induced loss
of consciousness

GHOST AVIATOR

Figure 15.1 — Increasing positive G drains blood from the head: grey-out, then black-out, then G-induced loss of consciousness (G-LOC).

62.2 Tilted-Back Seat — the DGCA-quoted mitigation

DGCA-QUOTED

A tilted back seat can reduce the chance of a black-out during positive G-manoeuvres.

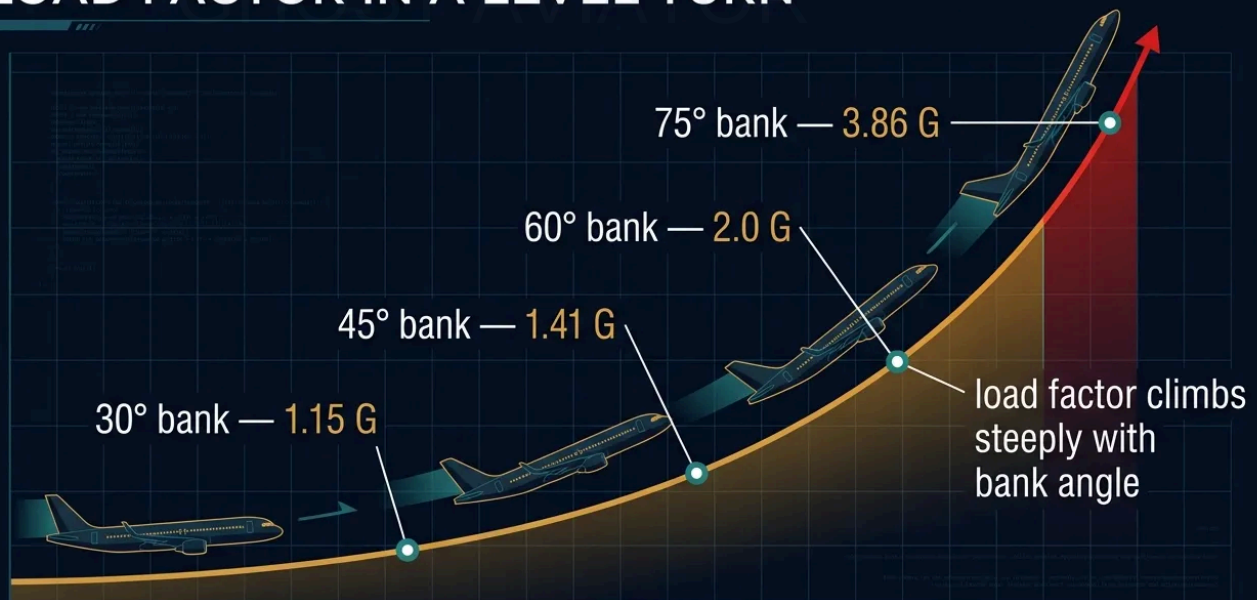
WHY A RECLINED SEAT HELPS

The taller the column of blood from the heart to the brain along the G-vector, the harder it is for the heart to pump against it. By **reclining the seat**, the vertical distance from the heart to the brain (measured along the seat-to-head axis, which is the G axis in a turn) is *reduced*. The blood column is shorter, the heart has less hydrostatic head to overcome, and cerebral perfusion is preserved at higher G loads. This is exactly why **fighter cockpits (F-16, etc.) recline the pilot's seat $\approx 30^\circ$** — to push the G-LOC threshold above where the airframe gives up first.

§ 63

1.41 G at 45° — the DGCA Reference Number

LOAD FACTOR IN A LEVEL TURN



GHOST AVIATOR

Figure 15.2 — Load factor in a balanced level turn: at a 45° bank the wings carry 1.41 G; it rises steeply with bank angle.

DGCA-QUOTED — EXACT LOAD-FACTOR REFERENCE

1.41 G is the acceleration experienced in a **LEVEL TURN** at **45° angle of bank**. In normal flying, angles of bank greater than this are not usually necessary.

Any physical disorder or immoderate consumption of alcohol or tobacco will reduce the body's tolerance to accelerations in excess of 1 G.

Load factor (n) vs bank angle in a level turn — $n = 1/\cos(\text{bank})$

Bank Angle	Load Factor (G)	Notes
0° (level flight)	1.00 G	Straight & level
15°	1.04 G	Shallow turn
30°	1.15 G	Standard rate turn (most light a/c)
45°	1.41 G	DGCA reference · upper limit of "normal flying"
60°	2.00 G	Steep turn · weight doubles
70°	3.00 G	Aerobatic turn
75°	3.86 G	—
80°	5.76 G	—
85°	11.5 G	Far beyond airframe / human limits

45° Maximum "normal" bank — DGCA quoted

1.41 G Load factor at 45° level turn

↓ tol. Reduced by disorder / alcohol / tobacco

§ 64

Factors Adversely Affecting G-Tolerance

DGCA-QUOTED — THE SIX FACTORS (VERBATIM, IN ORDER)

1. **Alcohol.**
2. **Smoking.**
3. **Fatigue.**
4. **Excessive heat.**
5. **Obesity.**
6. **Sickness.**

Join live classes for guided practice and doubt clearing.

Ghost Aviator | Free DGCA study notes

ghostaviator.com

[Telegram](#)

[Instagram](#)

[YouTube](#)

[Live classes](#)

6 / 8

Why each factor reduces G-tolerance

Factor	Physiological Effect
Alcohol	Vasodilation + dehydration + histotoxic hypoxia (§14) — blood pressure regulation degraded.
Smoking	5–8 % O ₂ -capacity loss + vasoconstriction + CO competition (§13) — less reserve when cerebral flow falls.
Fatigue	Cardiovascular reserve drops; muscle tone (for AGSM) is weakened; reaction time slows.
Excessive heat	Vasodilation for cooling + reduced blood volume from sweating → lower BP under G.
Obesity	Reduced cardiovascular fitness; abdominal fat reduces effectiveness of the AGSM straining manoeuvre.
Sickness	Dehydration, low BP, weakness — all the above multiplied.

\$ 65

Negative G & Red-out

DGCA-QUOTED — TOLERANCE ASYMMETRY

Most pilots can learn to tolerate moderate increases in positive "G", but many find even the smallest exposure to negative "G" to be unpleasant.

DGCA-QUOTED — WHEN NEGATIVE G IS EXPERIENCED IN FLIGHT

During flight negative "G" is experienced if, after **pulling out of a steep dive**, the **control column is instinctively and firmly moved FORWARD** because the pilot might feel that he has his **nose too high in an attitude that may lead to a stall**.

DGCA-QUOTED — WHAT NEGATIVE G DOES TO THE BODY

Negative "G" manoeuvres **INCREASE** the flow of blood **TO THE HEAD**. Blood pressure there increases, the face becomes very **FLUSHED**, and the **EYES BULGE**. The combined effect of these symptoms causes what is described as a **"RED OUT"**.

To relieve symptoms select a normal flying attitude.

POSITIVE G → BLACK-OUT

- Blood pulled **away from** head, into legs
- Cerebral perfusion falls
- Cascade: tunnel → grey → black
- Can progress to G-LOC (G-induced LoC)
- **Tolerable up to ~6 G** with training (light aerobatic limit)

NEGATIVE G → RED-OUT

- Blood pushed **into** the head
- Cerebral & ocular pressure rise

Join live classes for guided practice and doubt clearing.

- Face flushes red, eyes bulge
- "Red-out" — vision tinged red
- **Even small exposures unpleasant**
- Mitigation: **return to normal flying attitude**

WHY PILOTS ARE FAR WORSE AT NEGATIVE G THAN POSITIVE

Human cardiovascular anatomy is built for a 1 G "head-up" world. We have valves and reflexes that, under positive G, pump blood upward against gravity (the baroreceptor + sympathetic reflex). Under **negative G the body has NO compensatory mechanism** — blood floods the head, ocular and intracranial pressure rises, and small blood vessels in the eyes and brain can rupture. Even highly trained aerobatic pilots rarely tolerate more than **−3 G** sustained.

✦ END OF CHAPTER 15 ✦

Ghost Aviator | Human Performance & Limitations | Chapter 15 — The Forces | CPL · ATPL · DGCA HPL

Ghost Aviator · in service of every student pilot. Free, correct, and complete.

GHOST AVIATOR