

# Radiation Effects – Modulating Factors and Risk Assessment – An Overview

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# Stochastic Health Effects

- *Stochastic health effects* (cancer and hereditary disease) are the subject of everyday radiological protection, i.e. low dose or low dose-rate exposures to ionising radiation.
- Stochastic health effects are dominated by the future risk of *cancer* in the exposed individual, so cancer is usually the main concern of radiological protection.

# Cancer Epidemiology

- In the absence of sufficient radiobiological knowledge, quantitative risks of cancer following exposure to radiation must be obtained from the epidemiological study of suitably exposed groups of humans.
- Empirical models of cancer risk are obtained from these studies, guided by inexact radiobiological understanding.

# Atomic Bomb Survivors

- The principal (but not the only) source of data for cancer risk models is the Japanese survivors of the atomic bombings of Hiroshima and Nagasaki in 1945.
- Recent models are based largely on mortality data for leukaemia and cancer incidence data for solid tumours, generated by the studies of the Japanese atomic bomb survivors.

# Cancer Risk Models

- BEIR VII specific cancer risk models
  - leukaemia (except CLL), thyroid, stomach, colon, liver, lung, breast, bladder, *ovary*, *prostate*, *uterus*, and all other solid tumours combined.
- UNSCEAR specific cancer risk models
  - leukaemia (except CLL), thyroid, stomach, colon, liver, lung, breast, bladder, *oesophagus*, *bone*, *brain/CNS*, *non-melanoma skin*, and all other solid tumours combined.

# ICRP Cancer Risk Models

- ICRP specific cancer risk models
  - leukaemia (except CLL), thyroid, stomach, colon, liver, lung, breast, ovary, bladder, oesophagus, and all other solid tumours combined.
- ICRP nominal cancer risk coefficients
  - bone and skin (for which specific cancer risk models were not developed because of insufficient data).

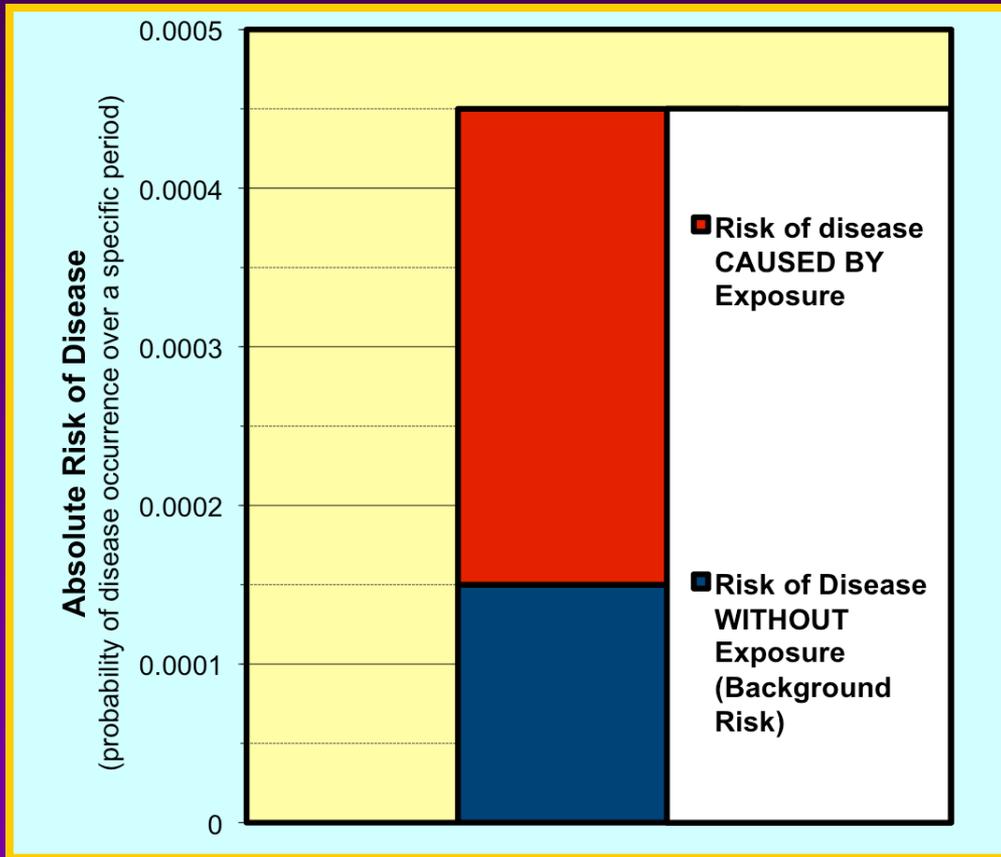
# Lung Cancer and Radon

- The risk of lung cancer following exposure to radon and its radioactive decay products is obtained from studies of underground hard-rock miners.
- Radon-induced lung cancer risk model was developed by the BEIR VI Committee (and by the ICRP in a forthcoming report).
- Evidence supplemented by studies of residential exposure to radon.

# ERR and EAR

- Cancer risk models may be expressed as either the **Excess Relative Risk (ERR)** or the **Excess Absolute Risk (EAR)**.
- The **ERR** is the proportional increase in risk over the background absolute risk (in the absence of exposure).
- The **EAR** is the additional risk above the background absolute risk.

# Measures of Risk



- **ERR** =  $(0.00045 - 0.00015) / 0.00015$   
= 2

- **EAR** =  $0.00045 - 0.00015$   
= 0.0003

# Factors Governing Risk

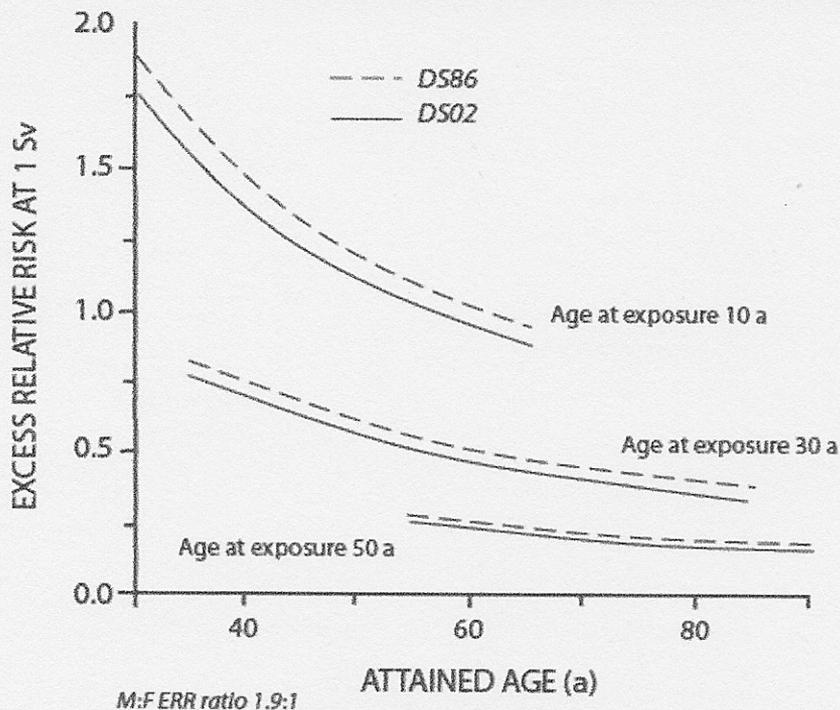
- The degree of risk of radiation-induced cancer is governed by –
  - Type of cancer
  - Tissue-specific absorbed dose
  - Dose-rate (low LET radiations)
  - Radiation quality (RBE)

# Risk Modifying Factors

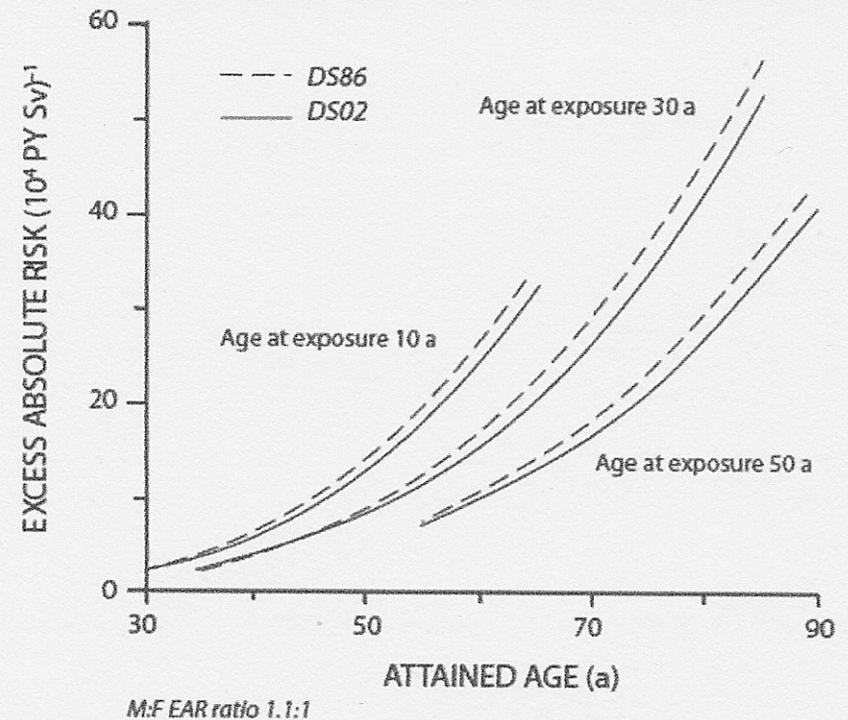
- Cancer-specific risk models incorporate intrinsic factors that significantly modify the radiation-related excess risk.
- Risk modifying factors –
  - Sex
  - Age-at-exposure
  - Time-since-exposure
  - Attained age (or Age-at-risk)
- Not all of these modifying factors are incorporated into each cancer-specific model.

# Age Modification of Risk

Sex-averaged solid cancer Excess Relative Risk



Sex-averaged solid cancer Excess Absolute Risk

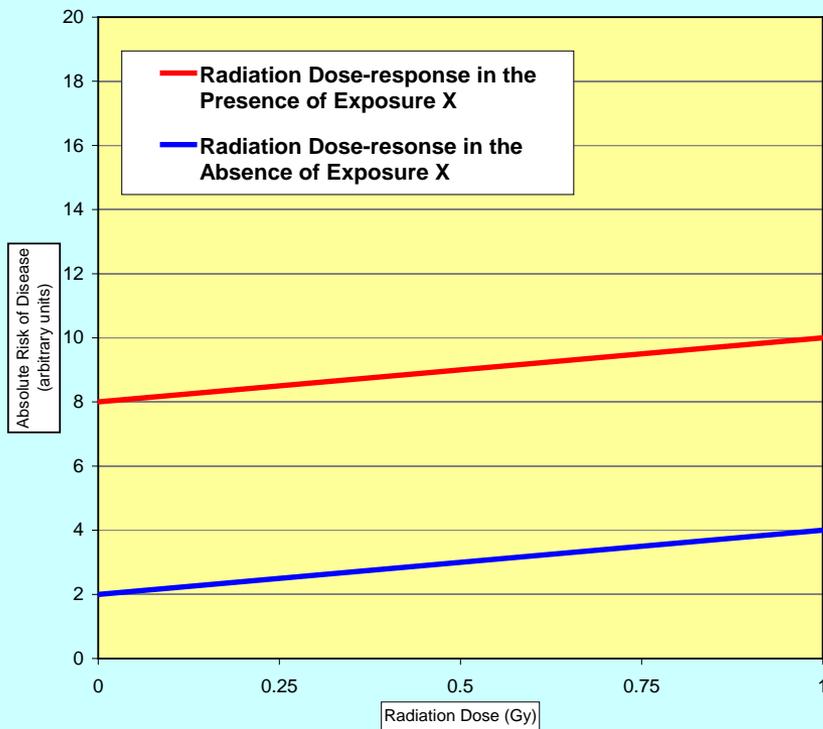


# Interaction with Other Risks

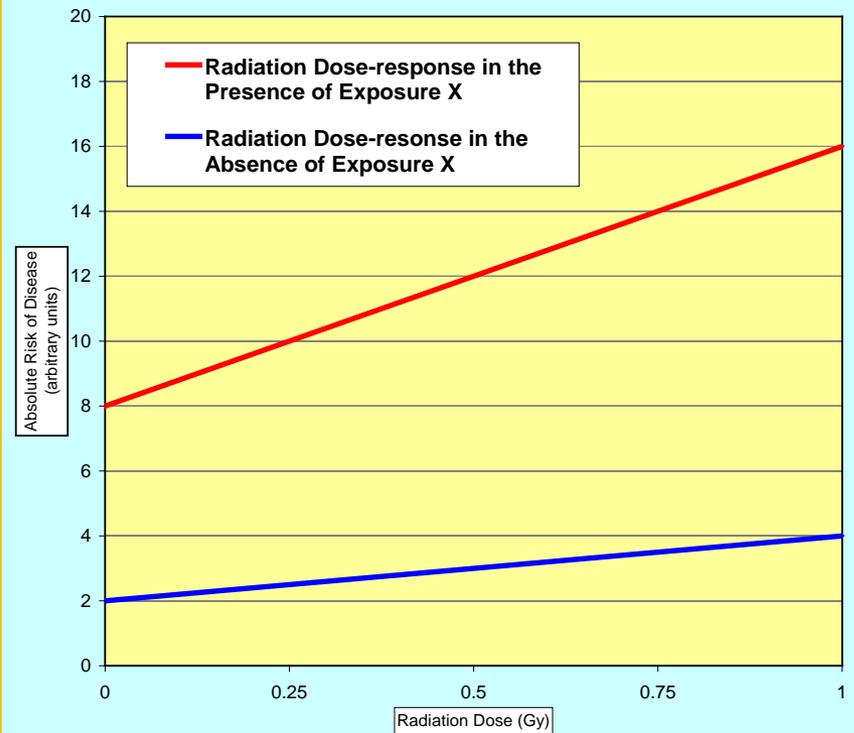
- The nature of any (aetiological/mechanistic) interaction between radiation and other (major) risk factors for a particular cancer will affect the radiation-related excess risk.
- The radiation-related excess risk will be greater if an interaction is involved.
- For example, the risk of radon-induced lung cancer is greater for smokers than for non-smokers.

# Interaction with Other Risks

Additive (No) Interaction between Radiation and Exposure X



Multiplicative Interaction between Radiation and Exposure X



# Transfer of Risk

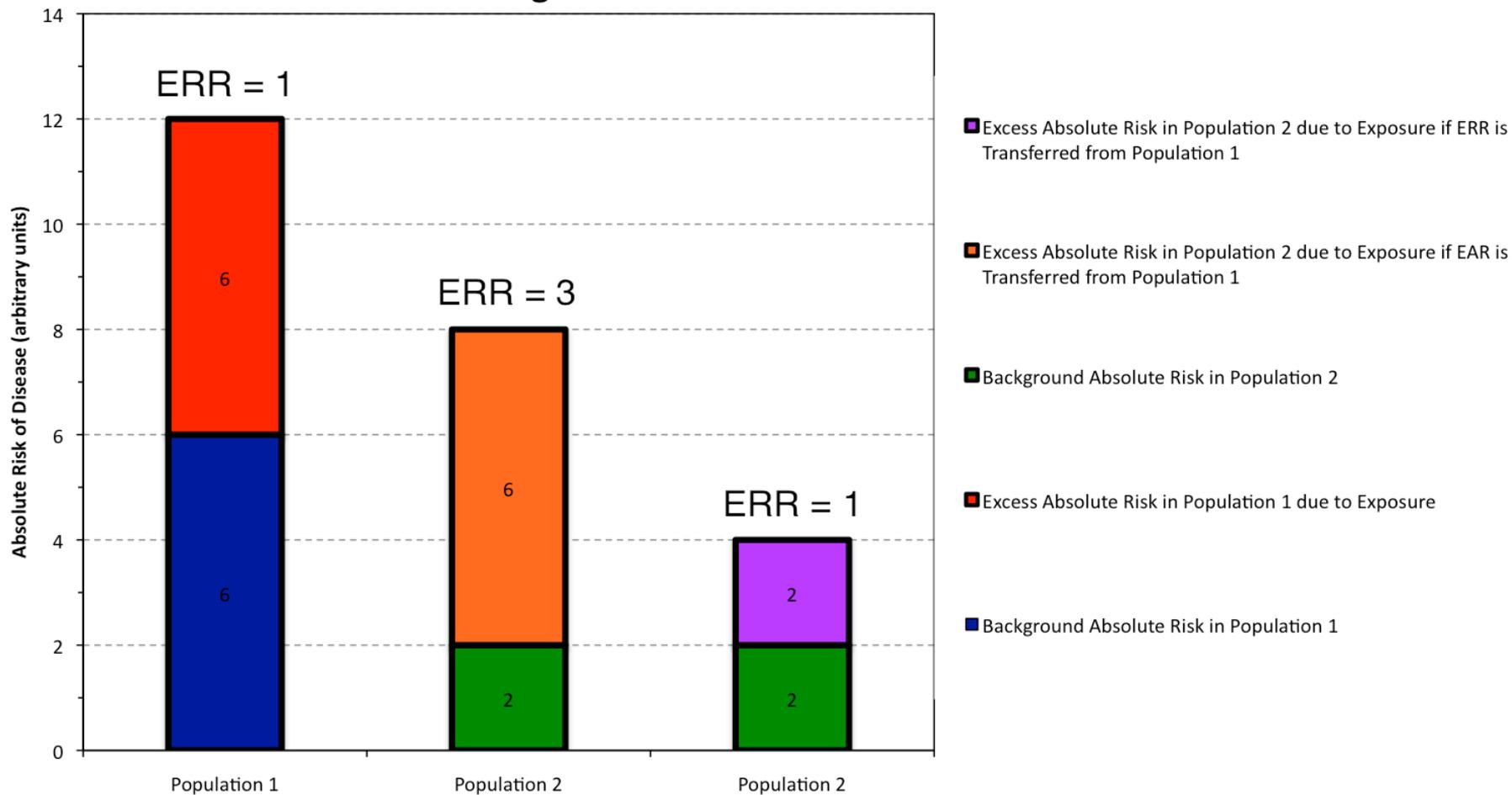
- Whether the cancer risk model is expressed in terms of the ERR or the EAR is not usually of importance for the population that generated the data from which the risk model was developed (e.g. for the Japanese atomic bomb survivors).
- *However*, whether the ERR or the EAR is transferred to another population will be important if background risks are materially different.

# Transfer of Risk

- Examples are stomach cancer and breast cancer in the Japanese and Western populations.
- In Japan, stomach cancer has a substantially higher incidence rate than in the West.
- In the West, breast cancer has a substantially higher incidence rate than in Japan.

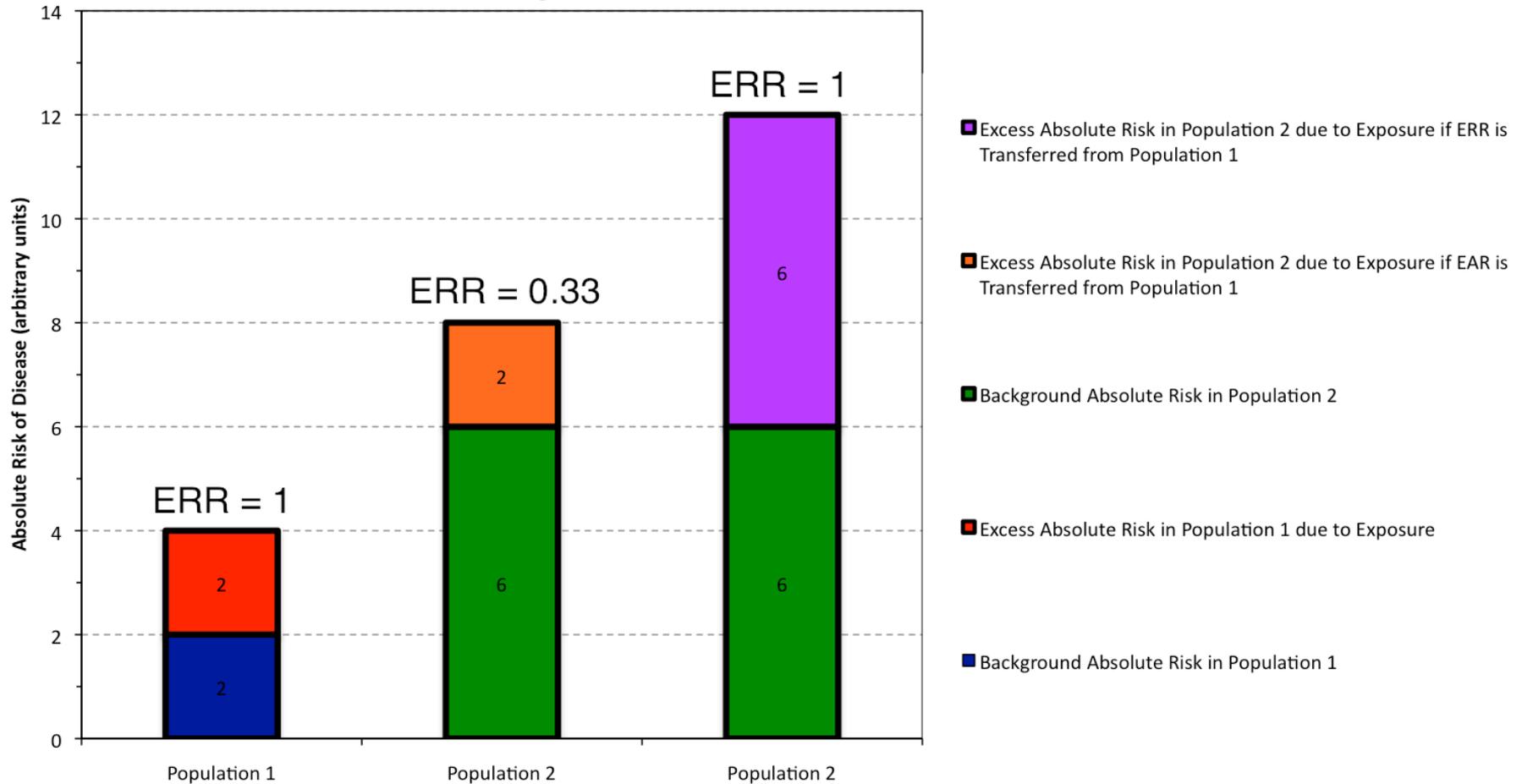
# Transfer of Risks

Transfer of Radiation-related Risk between Populations with Differing Background Absolute Risks of a Disease



# Transfer of Risks

Transfer of Radiation-related Risk between Populations with Differing Background Absolute Risks of a Disease



# Transfer of EAR or ERR

- If the **EAR** is transferred between populations then the background risk does not affect the radiation-related excess risk – the radiation-related risk is independent of the background risk.
- If the **ERR** is transferred between populations then the background risk does affect the excess radiation-related risk – the radiation-related excess risk is not independent of the background risk.

# BEIR VII Transfer of Risk

- BEIR VII (2006)
  - 70% ERR/30% EAR mixture for all cancer types with the exception of
  - thyroid cancer: 100% ERR
  - breast cancer: 100% EAR
  - lung cancer: 30% ERR/70% EAR mixture
- BEIR III (1980)
  - 100% EAR for all cancer types
- BEIR V (1990)
  - 100% ERR for all cancer types

# ICRP Transfer of Risk

- ICRP (2007)
  - 50% ERR/50% EAR mixture for all cancer types with the exception of
  - thyroid and skin cancers: 100% ERR
  - breast cancer and leukaemia: 100% EAR
  - lung cancer: 30% ERR/70% EAR mixture
- ICRP (1990)
  - 50% ERR/50% EAR mixture

# Transfer of Risk

- Risk transfer models containing a significant component of ERR transfer, and where background risk levels differ substantially, imply a material interaction between radiation and (at least some of) the major risk factors that determine the level of background risk of a particular type of cancer.

# Example – Tobacco Smoke

- Changing patterns of cigarette smoking produce complex patterns of lung cancer incidence, e.g. in the Japanese survivors.
- The lung cancer risks from cigarette smoke and radiation are more than additive, i.e. there is some component of ERR transfer.
- Radiation and tobacco smoke interact in their effect upon lung cancer risk.

# Conclusions

- Apart from the tissue-specific absorbed dose, it is established that risk is affected by dose-rate (at least, for some radiations/cancers) and radiation quality (RBE).
- Also established that risk is modified by sex, age, time-since-exposure, but the modifying effects are cancer-specific.

# Conclusions

- A significant component of ERR transfer implies a radiation-related excess risk that is dependent upon (at least some of) the major risk factors that influence the background risk of a particular cancer.
- For an individual, the risk of exposure to radiation is modified by the level of his/her background risk factors – reasonably well established for lung cancer and cigarettes.