

# INTEGRATION OF THE CARDIOVASCULAR CLINICAL RISK PREDICTION MODEL ASTRO-CHARM INTO THE NASA RADIATION RISK MODEL

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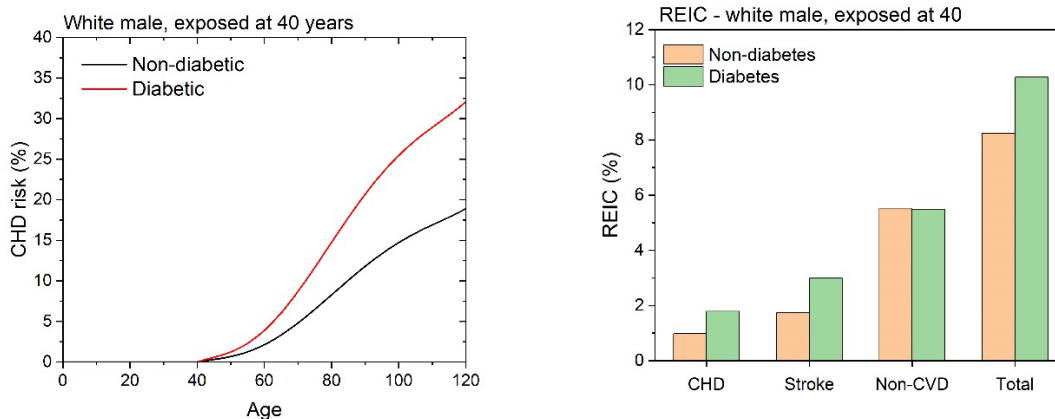
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## INTRODUCTION

Space radiation poses an increased risk for cardiovascular diseases (CVD) during and after spaceflight [1], that should be quantified to plan future space missions such as the flight to Mars. The radiation-induced CVD risk is evaluated using a linear no-threshold dose response excess relative risk (ERR) model [2], so that the risk is function of the radiation dose and of the background (i.e., non-exposed) incidence rate. The background CVD risk can be evaluated using clinical prediction models (CPMs) [3]. The first CPMs developed in the 1960's have identified CVD risk factors such as blood pressure, diabetes, cholesterol, and smoking. In this work, the steps used to integrate the CVD risk provided by a CPM into the NASA Radiation Risk Model are described. Simulation results calculated using available data for relevant mission scenarios are also shown, and the challenges in CVD risk predictions are discussed.

## MATERIAL AND METHODS

In the NASA Space Radiation Risk Model, radiation exposure-induced cases (REIC) and radiation exposure-induced death (REID) are used to quantify the risk attributable to radiation over a lifetime after exposure. These calculations require incidence and mortality rates adjusted for radiation exposure for different cancer types, coronary heart disease (CHD), and stroke, tabulated by years. For CHD and stroke, the post-exposure incidence and mortality rates are calculated using the CPM Astro-CHARM [4]. The first version of Astro-CHARM calculates the CVD risk at 10 years using traditional risk factors and biomarkers. An updated Astro-CHARM comprises different calculators for coronary heart diseases (CHD), stroke, congestive heart failure and global CVD risk. For each category, there are four calculators using different parameters: the basic one (risk factors), and three others using risk factors, ethnicity, and a combination of biomarkers. The calculators provide risk at 10 and 30 years, and by years from 38 to 95 years.



**Figure 1.** Calculation of Astro-CHARM risk and REIC for diabetic and non-diabetic white male, all other parameters being identical (40 years old, non-smoker, SBP: 126 mm Hg, total cholesterol: 141 mg/dL, HDL: 67 mg/dL, no family history, no medication for hypertension, no statin).

## DISCUSSION

The calculations in Figure 1 show a substantial effect of diabetes on the overall CHD risk, which is reflected in the REIC as well. As astronauts are healthy, using a CPM that includes risk factors and biomarkers to calculate background incidence and mortality rates, is preferred because the CPM will more closely represent the individual astronaut [3], allowing calculation of a personalized risk.

## REFERENCES

[1] Patel Z. et al (2020) *npj Microgravity* 6.1, 1-13. [2]. Little M.P. (2022) *BMJ* 380:e072924. [3]. Huff J.L et al (2022) *Front Cardiovasc Med* 1260. [4]. Khera A. et al (2018) *Circulation* 138, 1819-1827.

\*Disclaimer: This work was prepared while Z.S. Patel was employed at KBR. The opinions are the author's own and do not reflect the view of the NIH, the Department of Health and Human Services, or the United States government.