Is the ''Heart Age'' Concept Helpful or Harmful Compared to Absolute Cardiovascular Disease Risk? An Experimental Study

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Background. *Cardiovascular disease (CVD) prevention guidelines are generally based on the absolute risk of a CVD event, but there is increasing interest in using 'heart age' to motivate lifestyle change when absolute risk is low. Previous studies have not compared heart age to 5-year absolute risk, or investigated the impact of younger heart age, graphical format, and numeracy.* ***Objective.*** *Compare heart age versus 5-year absolute risk on psychological and behavioral outcomes.* ***Design.*** *2 (heart age, absolute risk) × 3 (text only, bar graph, line graph) experiment.* ***Setting.*** Online. ***Participants.*** *570 Australians aged 45–64 years, not taking CVD-related medication.* ***Intervention.*** *CVD risk assessment.* ***Measurements.*** *Intention to change lifestyle, recall, risk perception, emotional response, perceived credibility, and lifestyle behaviors after 2 weeks.* ***Results.*** *Most participants had lifestyle risk factors (95%) but low 5-year absolute risk (94%). Heart age did not improve lifestyle intentions and behaviors compared to absolute risk, was more often interpreted as a higher-risk category by low-risk participants (47% vs 23%), and decreased perceived credibility and positive emotional response. Overall, correct recall dropped from 65% to 24% after 2 weeks, with heart age recalled better than absolute risk at 2 weeks (32% vs 16%). These results were found across younger and older heart age results, graphical format, and numeracy.* ***Limitations.*** *Communicating CVD risk in a consultation rather than online may produce different results.* ***Conclusions.*** *There is no evidence that heart age motivates lifestyle change more than 5-year absolute risk in individuals with low CVD risk. Five-year absolute risk may be a better way to explain CVD risk, because it is more credible, does not inflate risk perception, and is consistent with clinical guidelines that base lifestyle and medication recommendations on absolute risk.* ***Key words:*** *cardiovascular disease; prevention; behaviour change; lifestyle change; risk assessment; risk communication; risk perception.* ***(Med Decis Making 2015;35:967–978)***

INTRODUCTION

Clinical guidelines for cardiovascular disease (CVD) prevention generally base medication recommendations on the absolute risk of a CVD event rather than on managing individual risk factors.[1] This is expressed as the short-term percentage risk of a cardiovascular event, usually over a 5- or 10-year time frame. However, adherence to these guidelines is suboptimal around the world,[2] and clinicians report difficulties in communicating absolute risk to patients.[3] Research has established that percentages are poorly understood by both patients and clinicians.[4,5] Moreover, the absolute risk concept may undermine lifestyle change messages for patients with low short-term CVD risk but elevated risk factors that increase their lifetime risk.[6,7] To address concerns that the absolute risk approach may miss opportunities to intervene before absolute risk becomes high, recent clinical guidelines in the United Kingdom advocate the use of ''heart age'' to communicate lifetime risk and motivate prevention measures when absolute risk is still low.[8]

Heart age is calculated by comparing an individual's current absolute risk to the age at which they

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would reach that absolute risk if they had ''ideal'' risk factors (e.g., a nonsmoker, systolic blood pressure 120 mmHg, and a total-to-HDL cholesterol ratio of 4).[9] Older heart age than current age indicates elevated but modifiable risk, even if the short-term absolute risk of a CVD event is low (see Box 1). Younger heart age indicates that current risk factors are even lower than ''ideal'' levels. The New Zealand Heart Foundation introduced an online calculator to promote the use of absolute risk guidelines in 2010, including both short-term (5-year) absolute risk and heart age in a line graph format, showing how CVD risk will increase over time if current risk factors remain the same compared to if they were ideal.[9] A pre-post study suggested that this tool may increase clinician understanding and confidence regarding the use of absolute risk, but patient outcomes were not assessed.[10] Recent clinical guidelines in the United Kingdom specifically advocate using heart age for lower-risk patients and even include medication recommendations based on heart age.[8] The rationale for this change is that heart age reflects lifetime risk, and could potentially motivate patients with low short-term risk to improve their lifestyle before their risk becomes high. However, there is little evidence that heart age is more effective than other risk formats. Previous studies have not directly compared heart age to 5-year absolute risk, and have not investigated the impacts on patients of being told they have younger compared to older heart age and of which graphical format they see.

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Qualitative studies suggest that patients may prefer heart age over other formats but raise concerns about its negative emotional impact. A focus group study using hypothetical risk found that patients liked heart age but were concerned it may frighten people if it is higher than their current age.[11] A ''think-aloud'' study in which patients used online CVD risk tools to calculate their actual heart age found that patients often misunderstand and discredit the results of heart age calculators, but they were prompted to consider lifestyle changes regardless of whether they believed the result or had a negative reaction to older heart age.[12] Quantitative studies suggest that heart age may be effective for motivating lifestyle change and reducing CVD risk factors, but there is little direct evidence that it is more effective than alternative risk formats. An experimental study found that heart age improved understanding of risk compared to 10-year absolute risk and had more emotional impact for younger people at higher risk. Emotional impact also mediated the relationship between risk level and intention to change lifestyle for both formats.[13] Comparison of heart age to 5-year absolute risk has not been addressed in previous studies, but a review of hypothetical absolute CVD risk formats suggests that shorter time frames ($<$10 years) may improve the accuracy of risk perception and increase intentions to change behavior compared to longer time frames (10 years or more).[14] Clinical trials have found that risk communication including heart age, and the similar concept of lung age, can motivate behavior change and improve risk factors, but these age-related formats were not directly compared to alternative risk formats.[15,16]

There is no consensus on the ''best'' way to present quantitative health risks in the broader risk communication literature, but the review of CVD risk formats mentioned above recommends graphical presentation.[14] Best practice guidelines suggest that graphical formats have mixed effects compared to text-only presentations, and their benefit may depend on individual differences in numeracy and literacy.[17,18] However, there is some research to suggest that bar graphs and frequency-based icon arrays can be beneficial for understanding health risks, particularly for people with lower numeracy.[19] This effect may be due to reducing various cognitive errors in the interpretations of textual expressions of risk, such as denominator neglect.[18,20] Because heart age is based on a comparison to ideal risk but does not directly relate to frequencies, bar graphs comparing actual versus ideal risk assessment results were used in this study, as an alternative to text-only and line graph formats.

Previous research has not investigated the effect of heart age compared to 5-year absolute risk, which is currently used in Australian and New Zealand guidelines, charts, and online tools.[9,21] Nor have there been any studies investigating the effect of communicating younger heart age, or presenting heart age in different graphical formats. This study aimed to address these gaps in the literature by experimentally testing the effect of heart age on psychological and behavioral outcomes compared to 5-year absolute risk in low- (i.e., 5-year absolute risk of a CVD event <10%) to moderate-risk (10–15% absolute risk) patients, according to the Australian guidelines.

METHOD

Design

A 2 × 3 factorial design was used to investigate the effect of CVD risk format (5-year absolute risk, and heart age) and different graphical formats (text only, text + bar graph, and text + line graph) on psychological and behavioral outcomes. The full study protocol is provided in the supplementary material, including examples of all presented CVD risk formats. This article focuses on the effect of heart age compared to 5-year absolute risk on the main outcomes of interest in previous heart age literature (recall, perceived risk category, emotional response, perceived credibility, intention to change lifestyle, and self-reported behavior change). See Figure 1. Additional psychological outcomes were assessed to explore possible mechanisms for any effect of heart age on lifestyle intention (alternative risk perception measures: numerical risk, verbal risk, comparative risk, feeling of risk;[22] and illness representation measures: worry about heart disease, perceived control and timeline of heart disease, subjective understanding of heart disease[23,24]). However, because the hypothesized effect of heart age on lifestyle intentions was not found, main effects and interactions between risk and graphical formats for these additional outcomes are reported as exploratory analyses in the supplementary material.

Sample Size

The a priori sample size calculation indicated that 85 participants per group, totaling 510 participants, would provide 90% power to detect a moderate effect size of d=0.5 (standardized difference) in the primary outcome of intention to change lifestyle as measured immediately postintervention, assuming a 2-sided alpha of 0.05. We aimed to recruit 20% more cases to account for potential dropout at 2-week follow-up.

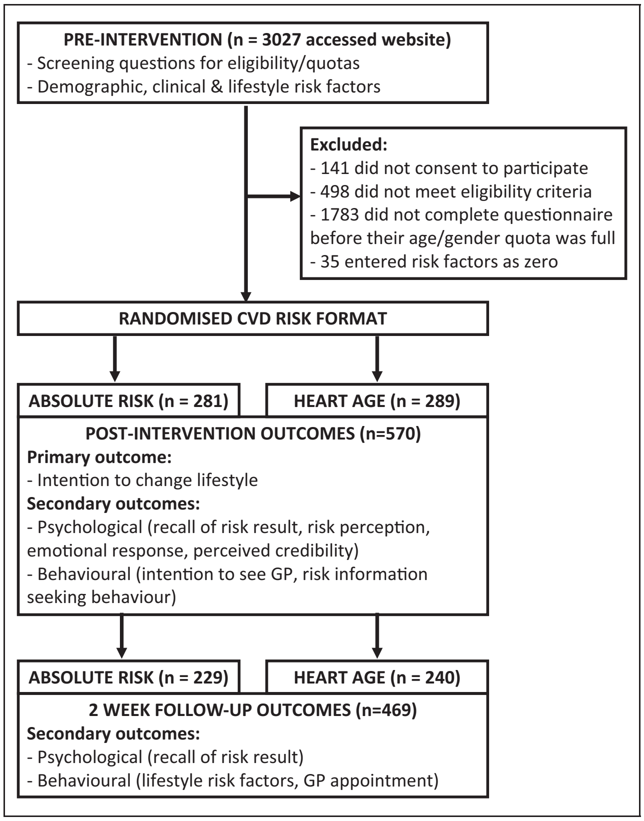

Figure 1 *Study design.*

Recruitment

A national Australian sample was recruited through a market research company (SSI: Survey Sampling International) in 2014. Sampling quotas were set to ensure equal participant numbers by gender and 5-year age group, because these are important determinants of CVD risk and we aimed to recruit participants with both younger and older heart age results at a range of ages. The eligibility criteria were being aged 45–64 years, not currently taking blood pressure or cholesterol-lowering medication, nondiabetic, not already known to be at high risk of CVD based on criteria in the Australian guidelines, and being able to read health-related information in English without help most of the time. Participants were recruited via e-mail or by visiting the SSI website independently. They received points for participating in the study, which they could redeem for entry into prize draws through SSI's online system.

Materials

Participants completed a CVD risk assessment based on Australian absolute risk guidelines and the New Zealand Heart Foundation's approach to calculating heart age, using the 5-year Framingham risk equation[9,21,25] and determining heart age by comparing a participant's current absolute risk to the age at which they would reach that absolute risk if they had ''ideal'' risk factors (i.e., nonsmoker, systolic blood pressure 120 mmHg, and a total-to-HDL cholesterol ratio of 4). If blood pressure or cholesterol was not known, the average by age and gender was used based on data from nondiabetic participants who were not taking blood pressure or cholesterol-lowering medication in the AusDiab study—a longitudinal study of 11,000 people investigating diabetes prevalence in Australia.[26] If participants indicated that a health professional had told them their blood pressure and/or cholesterol was raised, one standard deviation was added to the average for their age and gender. An example of the text for different risk formats is provided in Box 1, with additional examples in Box 2, and graphical presentation formats provided in the supplementary material.

Box 1 Example of Randomized Risk Formats

A 50-year-old male smoker with blood pressure = 130/80 mmHg and cholesterol ratio = 4 would be compared to a 50-year-old male with ''ideal'' risk factors (nonsmoker, blood pressure = 120/80 mmHg, and cholesterol ratio = 4), and receive his results in one of the following formats, depending on which group he was randomized to (note: nonsmokers did not receive information about quitting smoking; and heart age was set to a maximum of 74, in line with the Framingham model used in Australian guidelines and the New Zealand heart age tool).

***Absolute risk group*:**
''Your risk of having a heart attack or stroke in the next 5 years is 8%. If you stopped smoking and had lower blood pressure and cholesterol, your risk would be 3%. You can reduce your blood pressure and cholesterol by quitting smoking, improving your diet, and increasing physical activity.''

***Heart age group*:**
''Your heart age is 66, 16 years older than you. If you stopped smoking and had lower blood pressure and cholesterol, your heart age would be 50, the same as your current age. You can reduce your blood pressure and cholesterol by quitting smoking, improving your diet, and increasing physical activity.''

Box 2 Example of Text Results

All participants received their results in text format, with the exact wording depending on their randomized risk format (percentage risk or heart age), whether their calculated heart age result was older than, the same as, or younger than their current age, and whether they were a smoker or not.

***Older heart age result than current age, percentage risk format, nonsmoker*:**
''Your risk of having a heart attack or stroke in the next 5 years is 5%. If you had lower blood pressure and cholesterol, your risk would be 2%. You can reduce your blood pressure and cholesterol by improving your diet and increasing physical activity.''

***Older heart age result than current age, percentage risk format, smoker*:**
''Your risk of having a heart attack or stroke in the next 5 years is 17%. If you stopped smoking and had lower blood pressure and cholesterol, your risk would be 5%. You can reduce your blood pressure and cholesterol by quitting smoking, improving your diet, and increasing physical activity.''

***Same heart age result as current age, heart age format*:**
''Your heart age is 48, the same as your current age. Congratulations, this is the ideal result for your age and gender.''

***Younger heart age result than current age, heart age format*:**
''Your heart age is 45, 3 years younger than you. Congratulations, this is even better than the ideal result for your age and gender.''

Outcome Measures

The question format and response options for all measures are provided in the supplementary material. Demographic, clinical, and lifestyle risk factors were assessed pre-intervention. Numeracy was also assessed at this point using the validated Subjective Numeracy Scale.[27]

Psychological measures were assessed immediately postintervention:

1. The primary outcome was intention to change lifestyle (improve diet, increase physical activity, and stop smoking if applicable). This was assessed using a 3-item Likert-type scale from the Theory of Planned Behavior for each lifestyle aspect, a well-established approach in the behavioral science literature.[28] For example, for physical activity, participants rated the following statements from 1 (*strongly disagree*) to 7 (*strongly agree*) for the following items: I expect to do more physical activity in the next 2 weeks; I want to do more physical activity in the next 2 weeks; I intend to do more physical activity in the next 2

weeks. Average scores for each lifestyle aspect were calculated as well as the average across applicable lifestyle aspects (6 items for nonsmokers and 9 items for smokers).[28,29]

2. Recall of heart age or absolute risk result was assessed as correct (i.e., the exact right answer) or incorrect based on open numerical responses (and reassessed at 2-week follow-up).
3. Risk perception was assessed as the perceived risk category that the result indicated. In line with the Australian guidelines, low was defined as a 5-year absolute risk of a CVD event <10%, moderate as 10–15%, and high as >15% AR. These categories were not defined for participants in the study materials, because we were interested in the participants' own impressions of their risk level, not their understanding of the categories as defined by the Australian guidelines.
4. Emotional response was assessed using a 6-item Likert-type scale (from 0 [*none of this feeling*] to 10 [*a lot of this feeling*]), with positive (hopeful, optimistic, enthusiastic; α=.81) and negative (afraid, anxious, worried; α=.85) subscales scored based on the average of the relevant items, used in previous research on the role of affect in health risk information seeking.[30]
5. Perceived credibility was assessed with a 4-item Likert-type scale (from 1 [*completely disagree*] to 7 [*completely agree*]) scored as the average of the items (I felt that the numbers received were ''my numbers''; I found the results to be written personally for me; I felt that the information was relevant to me; I felt that the information was designed specifically for me; α=.89), used in previous research on the personal relevance and believability of online health risk assessments.[31]

Behavioral and lifestyle measures were assessed pre- and postintervention, and at 2-week follow-up:

6. Information seeking was assessed by providing 3 links in randomized order at the end of the postintervention questionnaire. Clicking on either of the 2 CVD-related links (to information about CVD risk and lifestyle on the Australian Heart Foundation website) was coded as a positive response; clicking on a link to Google or closing the browser was coded as a negative response, in line with the methods used in previous studies investigating online risk information seeking.[32]
7. Intention to see a general practitioner (GP) was assessed postintervention using a 3-item Likert-type scale for intention regarding the primary outcome, based on the average rating for the following statements from 1 (*strongly disagree*) to 7 (*strongly agree*): I expect to discuss my risk of heart disease with a doctor in the next 2 weeks; I want to discuss my risk of heart disease with a doctor in the next 2 weeks; I intend to discuss my risk of heart disease with a doctor in the next 2 weeks.[29] Participants also reported whether they had seen or made an appointment to see their GP at 2-week follow-up (response options: *yes* or *no*).
8. Smoking status was assessed pre-intervention and at 2-week follow-up with the question ''Do you currently smoke cigarettes?'' (Response options: *yes* or *no*.)
9. Physical activity was assessed pre-intervention and at 2-week follow-up using the 2Q-PA scale for moderate and vigorous physical activity, with a time scale of ''in the last week'' added. Adequate physical activity was defined as $\geq$3 vigorous sessions/week, $\geq$5 moderate sessions/week, or 1–2 vigorous sessions/week plus 3–4 moderate sessions/week.[33]
10. Diet was assessed pre-intervention and at 2-week follow-up using questions from a previous study on fruit and vegetable intake, modified to be consistent with Australian guidelines and the physical activity response options. Adequate diet was defined as having at least 2 servings of fruit and 5 servings of vegetables per day in the past week.[34]
11. Body mass index (BMI) was calculated using self-reported height and weight measures pre-intervention with options to provide this in either metric or imperial units. Clinically impossible values were recorded as missing.

Analysis

Continuous variables were described as mean (SD) or median (IQR: interquartile range) if the distributions were asymmetric. Categorical variables were summarized with percentages. The Mann–Whitney test (nonparametric) was used to compare groups among continuous outcomes, and the Chi square test was applied to categorical outcomes. We further explored the dependence of the results on participants' calculated heart age result (younger/same versus older than current age) and numeracy by testing an interaction using logistic and quantile (for the median) regressions for categorical and continuous outcomes, respectively. Finally, we compared the differences between the group arms for the primary outcomes, adjusted for characteristics that were slightly unbalanced among the groups after randomization, namely, gender, BMI, blood pressure assessed in the past year, and having been told the cholesterol level was high. For the categorical outcomes we performed the adjustment using logistic or multinomial regression, and for the continuous outcomes we used quantile regressions.

The significance level for all tests was set at 0.05.

RESULTS

Participants were recruited via e-mail or by visiting the SSI website independently, and quotas were set to achieve equal participant numbers in each age and gender category, so an exact response rate cannot be calculated. Of 3027 people who accessed the website during the recruitment period, 141 did not consent to participate, 498 did not meet the eligibility criteria, and 1783 did not complete the questionnaire before their age and gender quota was full, and their data were not recorded. Recruitment was closed after 605 participants had been randomized and completed the whole questionnaire. Of these 605 participants, 35 were excluded from the analyses because they specified their blood pressure and/or cholesterol values as zero, which meant the Framingham risk equation could not be calculated and they could not be shown their allocated CVD risk format. The remaining 570 participants were included in the analysis for postintervention outcomes, of which 469 participants (82%) completed the follow-up questionnaire for 2-week outcomes. See Figure 1. Baseline characteristics and calculated risk results for those included in the postintervention analyses are displayed in Table 1; psychological and behavioral outcomes are displayed in Table 2 and Figures 2 and 3.

Participant Characteristics

The randomized groups were similar in terms of CVD risk factors, with most participants having lifestyle risk factors (95% had inadequate physical activity, inadequate diet, higher than normal BMI and/or were current smokers) but low short-term absolute risk of a CVD event (94% had 5-year absolute risk <10%). Calculated heart age was on average 3 years older than current age (57 versus 54 years) with 63% of participants across randomized groups having a higher heart age than their current age, 1% having the same heart age as their current age, and 36% having a lower heart age than their current age.

Primary Outcome

For intention to change lifestyle (diet, physical activity, smoking, and the average of these), there were no significant differences between the absolute risk and heart age groups (see Table 2). There were no significant interactions with numeracy (i.e., there was no evidence that differences between the groups were affected by participants' numeracy). These results did not change after adjustment for gender, BMI, blood pressure assessed in the last year, or having been told the cholesterol was high.

Secondary Outcomes

Several differences between the absolute risk and heart age groups were found for secondary outcomes, and there were additional subgroup differences when participants with a younger or same calculated heart age were analyzed separately from participants with an older calculated heart age.

Recall

The majority of participants (65%) correctly recalled their risk result immediately postintervention, but this dropped to 24% after 2 weeks. Participants in the heart age group were more likely to correctly recall their risk result after 2 weeks compared to those in the absolute risk group across younger and older heart age results (32% versus 16%; $p < 0.001$;). For participants with a younger or same calculated heart age compared to current age, those who received their result in heart age format were more likely to correctly recall their result postintervention compared to those who received an absolute risk format (80% versus 63%; $p = 0.009$). The risk format did not make a difference to postintervention recall among participants with an older calculated heart age (61% for both formats; $p > 0.999$). As a sensitivity analysis, we tested whether there was any impact on the recall results when a margin of error was allowed for (ranging from 0.05 to 0.2 standard deviations). The results were similar, with recall better in the heart age condition. In fact, the heart age format was further favored because the error was much smaller in the heart age condition.

Risk Perception

Most participants (94%) were in the low-risk category according to Australian guidelines (5-year absolute risk of a CVD event <10%),[21] but only 53% of participants in the heart age group perceived the result as indicating a low risk of having a heart attack or stroke, compared to 77% in the absolute risk group ($p < 0.001$). Of the low-risk participants who

Table 1 Participant Characteristics and Risk Results by Randomized Risk Format (n = 570)

	Absolute Risk (n = 281)	Heart Age (n = 289)
Demographic Risk Factors		
Age, mean (*SD*)	54 (6)	54 (6)
Male, *n* (%)	134 (48)	153 (53)
Aboriginal or Torres Strait Islander, *n* (%)	3 (1)	4 (1)
Numeracy, median (IQR)	4.3 (3.4–5.0)	4.4 (3.6–5.0)
Lifestyle Risk Factors		
Body mass index (pre-intervention), *n* (%)		
Underweight	10 (4)	12 (4)
Normal	95 (34)	106 (37)
Overweight	92 (33)	99 (34)
Obese	81 (29)	70 (25)
Smoker (pre-intervention), *n* (%)	69 (25)	72 (25)
Cigarettes per day (pre-intervention), median (IQR)	15 (10–20)	15 (10–25)
Adequate diet* (pre-intervention), *n* (%)	50 (18)	51 (18)
Adequate physical activity† (pre-intervention), *n* (%)	124 (44)	128 (44)
Clinical Risk Factors		
BP assessed in last year, *n* (%)	207 (74)	197 (68)
Told BP raised by health professional, *n* (%)	45 (16)	42 (15)
Cholesterol assessed in last year, *n* (%)	144 (51)	142 (49)
Told cholesterol raised by health professional, *n* (%)	44 (16)	61 (21)
Systolic BP (value/estimate), mean (SD)	122 (11)	121 (9)
Cholesterol ratio (value/estimate), mean (SD)	3.8 (0.7)	3.8 (0.7)
Calculated Risk Results		
5-year absolute CVD risk, mean (SD)	4.3 (3.1)	4.3 (3.0)
5-year absolute CVD risk category, *n* (%)		
Low risk (<10%)	266 (95)	269 (93)
Moderate risk (10–15%)	14 (5)	20 (7)
High risk (>15%)	1 (0)	0 (0)
Heart age, mean (SD)	57 (11)	57 (10)
Younger heart age than current age, *n* (%)	107 (38)	100 (35)
Same heart age as current age, *n (%)*	3 (1)	4 (1)
Older heart age than current age, *n (%)*	171 (61)	185 (64)

*≥2 servings of fruit and ≥5 servings of vegetable per day, in the last week.
†≥3 vigorous sessions, ≥5 moderate sessions, or 1–2 vigorous sessions plus 3–4 moderate sessions, in the last week
BP: blood pressure; CVD: cardiovascular disease; IQR: interquartile range.

received their risk result in absolute risk format (n = 266), 78% perceived their result to be indicating low risk, 20% perceived it to be moderate risk, and 2% perceived it to be high risk. Of the low-risk participants who received their risk result in heart age format (n = 269), 56% perceived their result to be indicating low risk, 40% perceived it to be moderate risk, and 4% perceived it to be high risk (see Figure 2). For those with moderate or high risk, the effect of heart age is unclear. There were no significant differences between risk perception and actual risk by format (p = 0.071); however, the small number of cases (only 1 high-risk participant was randomized to the absolute risk arm) limits the conclusions for this group.

Emotional Response

Participants in the heart age group had a less positive emotional response (hopeful, optimistic, and enthusiastic) to the risk result compared to participants in the absolute risk group (median 5.0 versus 6.0; $p < 0.001$). Heart age also increased negative emotional response (afraid, anxious, and worried) compared to absolute risk, but this difference was not statistically significant (median 3.0 versus 2.3; $p = 0.40$; see Figure 3).

Perceived Credibility

Perceived credibility of the risk result (i.e., whether the results were believed or personally relevant) was

Table 2 Psychological and Behavioral Outcomes by Randomized Risk Format

	Absolute Risk (n = 281)	Heart Age (n = 289)	p-Value
Intention Outcomes (Postintervention)			
To reduce smoking*, median (IQR)	4.7 (3.7–6.0)	5.0 (4.0–5.7)	0.67**
To improve diet*, median (IQR)	4.3 (3.0–5.7)	4.0 (3.0–5.0)	0.47**
To improve physical activity*, median (IQR)	4.3 (3.5–5.7)	4.3 (3.7–5.3)	0.72**
To improve diet/PA or diet/PA/smoking†, median (IQR)	4.3 (3.5–5.5)	4.4 (3.5–5.2)	0.72**
To see GP for CVD risk assessment*, median (IQR)	2.0 (1.0–3.0)	2.0 (1.0–3.3)	0.35**
Psychological Outcomes			
Risk perception (postintervention)			
Results indicate low risk of heart attack/stroke, n (%)	216 (77)	154 (53)	
Results indicate moderate risk of heart attack/stroke, n (%)	60 (21)	121 (42)	<0.001††
Results indicate high risk of heart attack/stroke, n (%)	5 (2)	14 (5)	
Correct recall (postintervention), n (%)	173 (62)	195 (67)	0.17††
Correct recall (after 2 weeks), n (%)	37 (16)	77 (32)	<0.001††
Perceived credibility of results‡ (postintervention), median (IQR)	4.8 (4.0–6.0)	4.3 (3.3–5.3)	<0.001**
Positive emotional response§ (postintervention), median (IQR)	6.0 (5.0–8.0)	5.0 (4.0–7.0)	<0.001**
Negative emotional response§ (postintervention), median (IQR)	2.3 (1.0–4.7)	3.0 1.0–5.0)	0.40**
Behavioral Outcomes			
Information seeking (postintervention), n (%)	19 (7)	15 (5)	0.43††
Smoker (after 2 weeks), n (%)	58 (25)	55 (23)	0.62††
Cigarettes per day (after 2 weeks), median (IQR)	12 (6–20)	10 (3–20)	0.72**
Adequate diet‖ (after 2 weeks), n (%)	27 (12)	22 (9)	0.45††
Adequate physical activity¶ (after 2 weeks), n (%)	91 (40)	100 (42)	0.74††
Made GP appointment (after 2 weeks), n (%)	23 (10)	27 (11)	0.78††

Higher scores indicate more of the attribute.
*Average of 3 items on a 1–7 Likert-type scale (1 [*strongly disagree*], 7 [*strongly agree*]).
†Average of 6/9 items on a 1–7 Likert-type scale depending on smoking status (1 [*strongly disagree*], 7 [*strongly agree*]).
‡Average of 4 items on a 1–7 Likert-type scale (1 [*strongly disagree*], 7 [*strongly agree*]).
§Average of 3 items on a 0–10 Likert-type scale (0 [*none of this feeling*], 10 [*a lot of this feeling*]).
‖≥2 servings of fruit and ≥5 servings of vegetable per day in the past week.
¶≥3 vigorous sessions, ≥5 moderate sessions, or 1–2 vigorous sessions plus 3–4 moderate sessions, in the past week.
**Mann–Whitney test.
††Chi-square test
CVD: cardiovascular disease; GP: general practitioner; IQR: Interquartile range; PA: physical activity.

lower for participants in the heart age group compared to participants in the absolute risk group (median 4.8 versus 4.3; $p < 0.001$; see Figure 3).

Behavioral Outcomes

No risk format effects were found for secondary behavioral outcomes immediately postintervention (intention to see a GP or information-seeking behavior) or at 2-week follow-up (percentage adequate diet, adequate physical activity, smokers, or GP appointment for CVD risk assessment).

DISCUSSION

The results of this study indicate that online assessment of heart age is no more effective than 5-year absolute risk for increasing lifestyle change intentions and behavior, in a general population sample with lifestyle risk factors but mostly low short-term risk of a CVD event (mean 5-year absolute risk <5% in both groups). The sample size was sufficient to assess this as the primary outcome, so the result is unlikely to be due to a lack of power, and the sample characteristics reflected the target group for heart age communication in recent clinical guidelines advocating the use of heart age.[8] Compared to 5-year absolute risk, heart age was more likely to be interpreted as moderate and high risk by low-risk participants, decreased positive emotional response to the results, and decreased the perceived credibility of the risk assessment; however, heart age was more likely to be accurately recalled after 2 weeks. These effects were found across younger and older heart age results, and numeracy levels.

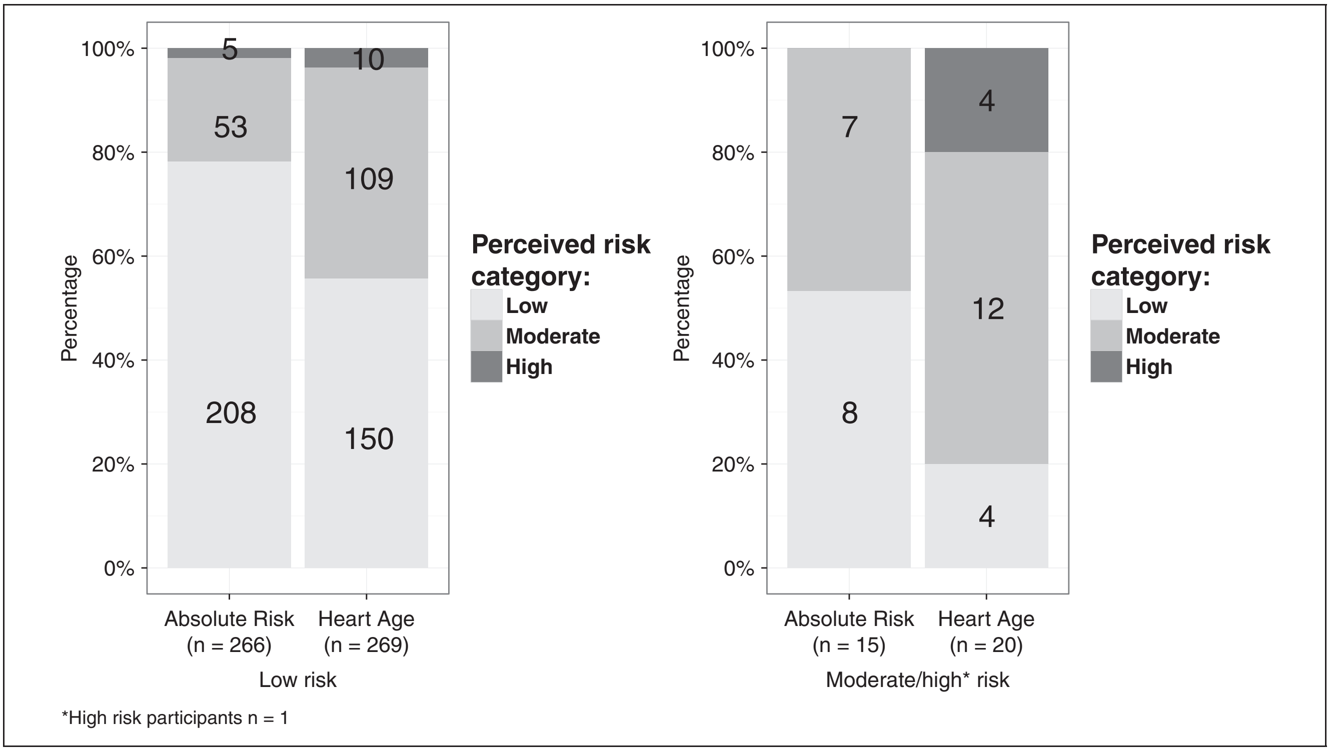

Figure 2 *Perceived risk category postintervention by randomized risk format group for individuals with actual low risk (5-year absolute risk <10%; left panel) and actual moderate or high risk (5-year absolute risk ≥10%; right panel). Please note that there was only 1 high-risk participant who was randomized to the absolute risk arm. The numbers in the bars indicate the absolute counts.*

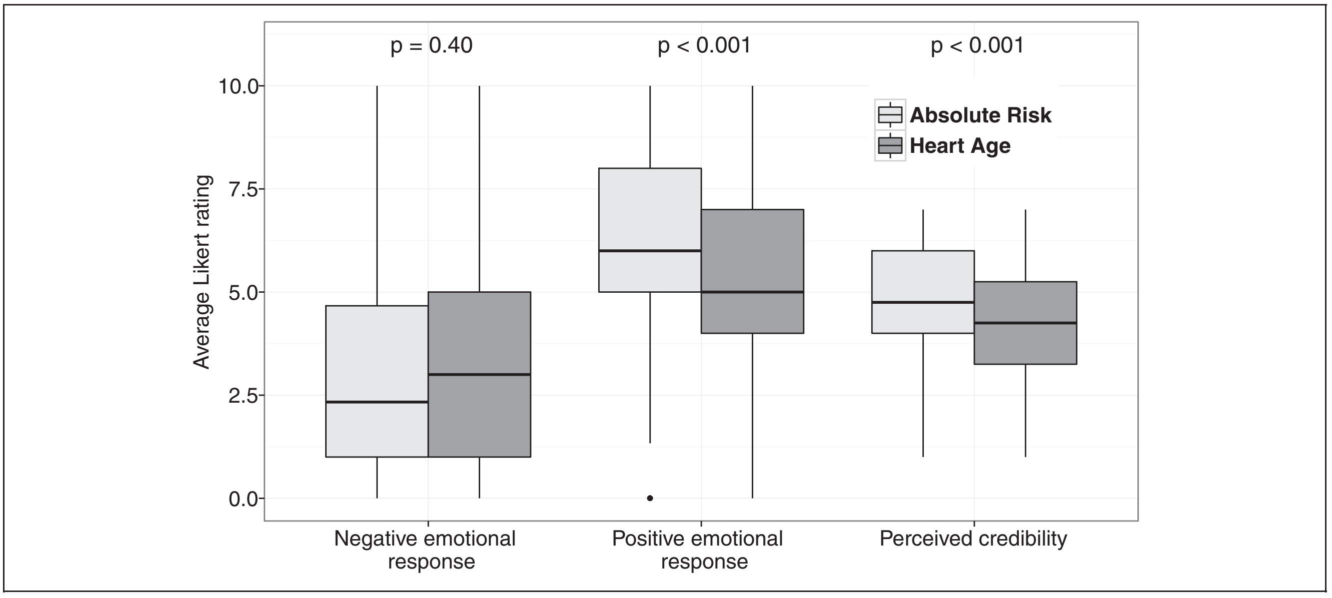

Figure 3 *Distribution of emotional response and perceived credibility postintervention by randomized risk format group.*

Our findings are in line with a recent experimental study that found adding heart age to salient absolute risk formats had no effect on lifestyle intentions[35] and contradict suggestions that it is more motivating than absolute risk in individuals with low CVD risk.[8,9,13] Five-year absolute risk is by definition a smaller number than 10-year absolute risk, and people have a tendency to ignore the base rate for probabilistic information, including the time frame of health statistics.[36] Moreover, people are so familiar with their own age that it stands as an available benchmark to compare heart age to. Theoretically, heart age could therefore be expected to have even more impact compared to 5-year rather than 10-year absolute risk, because the number indicating ''risk'' is smaller when a 5-year time frame is used. However, our findings suggest that the prospect of a CVD event in the short term has as much impact on lifestyle intention as the heart age format. This is supported by a previous review of absolute CVD risk formats that found that shorter time frames (<10 years) increase intentions to change behavior compared to longer time frames (10 years or more) in hypothetical studies.[14] The issue of low credibility identified in our previous qualitative study of online heart age calculators was also confirmed in this study: patients discredit the results of online heart age calculators, and perceive heart age as less credible than absolute risk.[12] The finding that heart age has more emotional impact and is more memorable than absolute risk supports previous quantitative and qualitative studies,[11–13] but this did not translate into greater intentions to change lifestyle. This is in contrast to a recent Spanish trial (published after this study was conducted) that found greater reductions in lifestyle and clinical risk factors for CVD after 12 months when patients were shown an interactive heart age tool by their clinician compared to usual care or communicating 10-year absolute risk in verbal format.[37] The discrepancy between these findings may be explained by the presentation formats used: The heart age group in the Spanish trial viewed an interactive, computer-based heart age tool demonstrating the effect of risk factor modification during a clinical consultation as well as the verbal format that the absolute risk group received (personal communication with corresponding author), so the effect may be attributed to a more compelling visual format rather than heart age per se. In the current study, the heart age and absolute risk groups viewed equivalent verbal and visual formats to enable a direct comparison (see supplementary material). Alternatively, 5-year absolute risk and heart age may both be superior to 10-year absolute risk but no different from each other, in terms of motivation to change lifestyle. The lack of impact of numeracy in this study contributes to the mixed findings in the broader risk communication literature.[18]

The main clinical implication of this study is that advocating heart age as a more effective risk communication format than absolute risk may be premature. Providing a 5-year absolute risk format may be a better way to explain risk to patients, because it is more credible, does not artificially inflate risk perception, and is consistent with clinical guidelines that base lifestyle and medication recommendations on absolute risk thresholds.[1] In contrast, heart age is recalled better, and assessment by a clinician may ameliorate the reduced credibility for heart age when provided via an online calculator. Assessment of heart age in a clinical consultation could also provide an opportunity to correct inaccurate risk perception and clearly explain the difference between short-term risk (e.g., 5-year risk of a CVD event) and lifetime risk (reflected by the heart age concept). An additional benefit could be improved use of the absolute risk guidelines by GPs, if communicating heart age rather than absolute risk drives greater confidence in using the guidelines.[10] Although these guidelines are targeted at clinicians, the online CVD risk and heart age calculators that support them are publicly available (www.jbs3risk.com and www.knowyournumbers.co.nz). Such health risk calculators are widely available online and used by consumers without clinician involvement,[38] so effective CVD risk communication formats for both clinical and online settings are needed.

The strengths of this study include a rigorous experimental design specifically testing heart age alone against 5-year absolute risk alone using equivalent verbal and visual formats, inclusion of a follow-up time point to assess behavior change as well as psychological outcomes, and a national sample in the target group for heart age communication (i.e., lifestyle risk factors but low short-term risk of a CVD event). The limitations include the use of a static online format, which may not be as impactful as an interactive website or clinician communication during a consultation; the use of information-seeking behavior as a proxy for actual behavior; the fact that we included only computer-literate participants and self-reported outcomes; and the need to exclude some participants due to inaccurate self-reported risk factor data.

The findings of this study could be extended by comparing the effect of communicating heart age versus 5-year absolute risk in clinical consultations using equivalent verbal and visual formats. Clinician involvement in communicating heart age may prevent the reduction in credibility and inaccurate risk perception found in this study, and exploratory analyses of risk and illness perceptions suggest that heart age may be useful in specific situations (see supplementary material). Further research is required to better understand the impact of the different formats on participants with moderate and high CVD risk because the majority of participants in this study were at low risk. Research should also confirm whether: 1) communicating text-based heart age or adding a bar graph that illustrates absolute risk is beneficial when GPs want to increase risk and illness perceptions for patients with low short-term absolute risk but lifestyle risk factors; 2) communicating younger heart age is beneficial for reducing risk perceptions among anxious low-risk patients, without demotivating good lifestyle behaviors; and 3) our findings hold when using different time horizons. Alternative ways to explain the difference between short-term and lifetime risk, and the relationship between heart age and absolute risk, could also be explored. Because the benefits of lifestyle are not restricted to CVD, less specific age-related formats such as ''biological age'' or ''real age'' may also be helpful for motivating lifestyle change without inflating CVD risk perception.

This study found that heart age was more memorable and had more emotional impact than 5-year absolute risk, but there was no benefit with respect to changing lifestyle intentions or behavior. Communicating 5-year absolute risk may be the better approach, because it is more credible, avoids inflating risk perception, and is consistent with clinical guidelines that base lifestyle and medication recommendations on absolute risk thresholds.

Author Contributions

Author contribution were as follows: study design (CB, JJ, BN, LI, AT, PG, JD, KM), recruitment (CB, SM), data collection (CB), analysis (CB, AT), interpretation (CB, JJ, BN, LI, AT, PG, JD, SM, KM), drafting (CB) and revising the manuscript (CB, JJ, BN, LI, AT, PG, JD, SM, KM). All authors approved the final version of the manuscript.

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ETHICAL APPROVAL

Ethical approval for the study was obtained through the Human Research Ethics Committee of The University of Sydney (Protocol No. 2013/914). Participation was anonymous.

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