The impact and perception of England's web-based heart age test of cardiovascular disease risk: A mixed-methods study

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Abstract

Background: It is well documented that individuals struggle to understand cardiovascular disease percentage risk scores which led to the development of heart age as a means of communicating risk. Developed for clinical use, its application in raising public awareness of heart health as part of a self-directed digital test has not been considered before.

Objectives: To understand who accesses England's heart age test and its effect on user perception, knowledge and understanding of CVD risk, future behaviour intentions and potential engagement with primary care services.

Methods: There were three sources of data: 1. Routinely gathered data on all those accessing the heart age test (Feb 2015-Jun 2020); 2. Online survey, distributed January-March 2021; 3. Interviews with a sub-sample of survey respondents (February-March 2021). Data were used to describe the test user population, explore knowledge and understanding of CVD risk, confidence in interpreting CVD risk and control of CVD risk, and the effect on future behaviour intentions and potential engagement with primary care. Interviews were analysed using reflexive thematic analysis.

Results: Between Feb 2015 and Jun 2020, the heart age test was completed almost 5 million times, with more completions by males (54.8%), those aged 50-59 years (27.2%), from a White ethnic background (81%), and those living in the least deprived 20% of areas (14.4%). The study concluded with 819 survey responses and 33 semi-structured interviews. Participants suggested they understood the meaning of a higher estimated heart age and self-reported at least some improvements to understanding and confidence in understanding and control of CVD risk. Negative emotional responses were provoked among users when estimated heart age did not equate to their prior risk perceptions. The limited information needed to complete it or the production of a result when physiological risk factor information was missing (i.e., blood pressure, cholesterol) led some users to question the credibility of the test. Yet, most suggested they would or had already recommended the test to others, would use it again in the future, would be more likely to take up the offer of a NHS Health Check, and self-reported that they had made or intended to make changes to their health behaviour or felt encouraged to continue to make changes to their health behaviour.

Conclusions: England's web-based heart age test has engaged large numbers of people on their heart health. Improvements to England's heart age test, noted in this paper, may enhance user satisfaction and prevent confusion. Future work to understand the longer-term benefit of the test on behavioural outcomes is warranted.

Clinical Trials: N/A

Keywords: Heart age; Cardiovascular disease; CVD Prevention; Online risk assessment; CVD Risk; Qualitative Research; Cross-sectional design; cardiology; Risk Assessment; Cardiovascular risk; Cardiology; Heart health; User perception; Risk knowledge; Engagement; Web-based

Introduction

Cardiovascular disease (CVD) remains the leading cause of death globally [1], with a quarter of all deaths in England reportedly due to heart and circulatory disease alone [2]. Communicating the risk of CVD to patients is challenging [3], and is influenced by several factors including patient understanding, health literacy and personality traits [4]. There is evidence that patients and practitioners struggle to interpret traditional risk formats such as short-term percentage risk scores used to communicate risk [5–9], which limits their potential to encourage individuals to adopt CVD risk-reducing behaviours [5]. In recent years, other CVD risk formats, including heart age calculators, have been developed to support health care professionals with CVD risk communication. Heart age is a reflection of lifetime risk, whereby an individual's chronological age is compared with someone of the same age, gender and ethnicity but with optimum modifiable risk factors [10]. If an individual has one or more risk factors (i.e., cholesterol, blood pressure) that are less than optimal, their heart age will be higher than their chronological age. There is evidence that use of heart age improves risk perception and recall and is more emotionally impactful [10–22], compared with other risk communication methods, such as percentage risk scores.

A web-based, version of the Joint British Societies derived 'heart age' test [23], developed by Public Health England, the British Heart Foundation, the Joint British Societies for the prevention of cardiovascular disease, and NHS Digital was first introduced in 2015 known as the heart age test (HAT) [24]. The HAT is freely accessible on the NHS website [25] and can be used to identify CVD risk among people over the age of 30 who do not have pre-existing CVD. The test was created to: raise awareness and increase understanding of CVD risk, provide information and signpost individuals to resources, improve heath literacy, and encourage individuals to take up the offer of an NHS Health Check (a vascular risk assessment offered to those aged 40 to 74 who have not been diagnosed with CVD, kidney disease or dementia, and diabetes)[26]. Early assessment of HAT usage shows more than 500,000 completions between February and July 2015, broadly representing the population demographic of England [24]. Other heart age calculators have also been developed, which has resulted in millions of users worldwide. These include Unicef's heart age tool, accessed across 13 countries between 2009-2011 [27]; the 'Your Heart Forecast', to promote clinical guidance in New Zealand [28], the Framingham version of heart age, to identify population estimates of heart age in the US and China [29,30]; and Australia's heart age calculator [31], created during a national consumer awareness campaign in 2019.

Despite their popularity, it has been noted that online CVD risk calculators (i.e., including heart age calculators) produce variable risk estimates, often fail to disclose the models upon which they were based, can result in limited understanding and concern regarding CVD risk, and poor behavioural intentions [13,32]. There is also the risk that heart age calculated based on incomplete data due to poor user awareness of physiological risk information is also poor [24,27], can lead to underestimation or overestimation of CVD risk [19,27], doubts about the credibility of the risk calculator [13,33], unnecessary primary care visits and clinical testing [31,34]. An evaluation of Australia's heart age calculator suggested it provoked a positive emotional response and led to self-reported health behaviour change (i.e., improvement to diet, physical activity and weight loss) and clinical checks for over half of survey respondents [31]. Despite such suggestions that communication of chronic risk through 'age concepts' may improve behavioural outcomes over percentage risk scores (i.e., lower

blood pressure, change in cholesterol, intentions to improve diet and increase exercise), a recent systematic review concluded that evidence remains limited [13,20].

There has been little research into England's web-based HAT. Given its apparent popularity based on data published in 2016 [24], the present study provides a necessary contribution to understand its use and possible impact. The aim of the study was to understand who is accessing England's HAT and its effect on knowledge and understanding of CVD risk, future intentions towards health behaviour change and potential engagement with primary care services.

Methods

Design

A mixed-method design was used. Data were collected in one of three ways: 1. HAT user data (aggregate data provided by Public Health England); 2. Open online survey; 3. Semi-structured interviews.

Ethics Approval

Ethical approval was received by *university - concealed for review* (Reference SU20-085/096/101). The procedures followed were in accordance with the ethical standards of the institutional committee and with the Helsinki Declaration of 1975. Participants were informed that completion of the online survey was deemed informed consent. Written and audio-recorded verbal consent was received by those who participated in a follow-up interview.

Settings and participants

As an online tool, there is no geographical constraint on who can access the test, therefore, HAT user data cannot be attributed to only those living in England.

Participants were adults (30 years and older) who had completed the HAT. The study setting was England, United Kingdom. Completion of the test was conducted online (via a link to the webpage; 29). As per the purposes of the study, participants who completed the online survey and follow-up interviews were required to be living in England at the time of participating in the research.

Processes and procedures

Recruitment

Information about the study (including the purpose, estimated time to complete the survey, data storage, the research team) and how to participate was presented to potential participants, prior to survey completion, through a URL; shared via several online platforms (i.e., Facebook, Twitter, university website [used by university staff, prospective and pre-existing students and academics], and the university's Centre for Health and Development newsletter). A pop-up was also created by NHS Digital and displayed on the HAT results page (on the NHS website; used by the general population to obtain health information) to promote the study. The survey was voluntary. Survey respondents were

invited to provide their contact information at the end of the online survey if they wished to participate in a follow-up interview to discuss their experience in more depth. Contact information was stored separately to data collected on a secure laptop and destroyed following study completion. Both the online survey and interview were incentivised to encourage individuals to participate (through a prize draw and individual retail vouchers respectively). Due to COVID-19 restrictions and the geographical spread of participants, interviews were conducted via telephone.

Data collection and analysis

User data

Aggregate quantitative data for HAT users provided by Public Health England were received by the research team in March 2021. The data were summarised to profile users of the HAT.

Open online survey

Data collection took place between January-March 2021, through an online survey, whereby participants were asked to complete the HAT before answering questions about their experience and impact of the test, future behaviour intentions and demographic profile (See supplementary file 1 for survey questions). Non-validated survey questions were created based on the aim of the study, through discussions between authors and the project steering group, and a previously unpublished survey created by Public Health England to understand the value of the HAT. Questions were presented across five pages (average 5 items per page), in the same order for all participants but using survey logic to omit certain questions where appropriate. Completeness checks were not conducted, and participation and completion rates were not recorded and therefore cannot be reported.

To meet the objectives of the evaluation, responses were analysed descriptively, and a summary of the findings are outlined.

Follow-up interviews

A sub-sample of survey respondents participated in a semi-structured, one-to-one telephone interview to talk about their experience and the effect of the tool on future behaviour intentions. An interview topic guide was used to support discussion (Supplementary file 2); informed through discussions between authors, the HAT steering group (including colleagues from NHS Digital, University College London and the British Heart Foundation) and a previously unpublished survey created by Public Health England to understand the value of the HAT. All participants who completed the interview were offered a £20 online retail voucher in appreciation of their time. Interviews were audio-recorded following participant consent and transcribed verbatim.

Data were analysed using inductive, reflexive thematic analysis [35,36]. This was appropriate for this type of enquiry, the size of the sample [37], and allowed for purposive sampling (from the subsample of survey respondents who expressed an interest in taking part in an interview), such that the interview sample was broadly reflective of the typical HAT users population (based on age, sex, ethnicity, deprivation). Processes followed those set out by Braun and Clarke [35]. Two researchers (first and third author) familiarised themselves with the data through extensive reading before preliminary codes and themes were identified. A sub-sample of transcripts (one in every five transcripts, 20% overall) were independently dual-coded by both researchers to check reliability of coding. Dual-coded transcripts were manually checked for discrepancies and indicated excellent

coding consistency. Both researchers reviewed all preliminary codes before agreeing initial themes. Themes were checked to ensure they were data driven and discussed with the second author before being finalised.

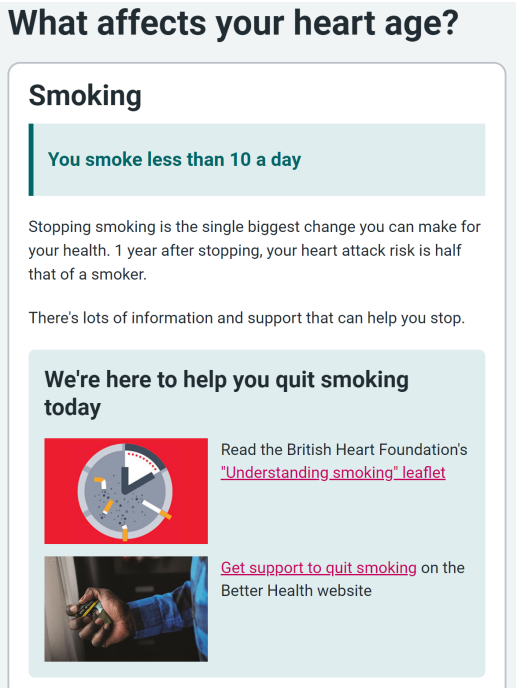
England's Heart Age Test

England's web-based HAT is based on the Joint British Societies risk calculator [23]. The calculator algorithm employs QRISK data to estimate individual 10-year CVD risk, lifetime risk and heart age. Users are required to input information on their age, sex, ethnicity, postcode (to derive deprivation estimate), smoking status, height, weight, blood pressure, cholesterol, family history of CVD and other information about their current health status (e.g., diagnosis of Type 2 diabetes, and Rheumatoid arthritis). This information is used to estimate and present heart age, and age of first CVD event (i.e., CVD event-free survival age; see Multimedia appendix 1).

Multimedia Appendix 1: Figure 1. Screenshot of heart age and CVD event-free survival age presented in HAT output

Heart age is calculated by comparing the user with someone of the same sex and ethnicity but with no individual elevated risk factors (i.e., blood pressure, cholesterol, family history of CVD). If the user is unable to provide information about their blood pressure and cholesterol, UK national averages are included to calculate their risk. Following the results, the test also provides the user with advice tailored to the individual's risk factor profile [e.g., smoking status, weight, cholesterol and blood pressure (see Multimedia Appendix 2 for an example screenshot of risk-tailored information and advice around smoking presented in HAT output)].

Multimedia Appendix 2: Figure 2. Screenshot of risk tailored information and advice presented in HAT output



Results

User data

Between February 2015 and June 2020, there were 4,898,532 calculated HAT cases (the test can be completed more than once by the same individual). Users were most commonly male (2,682,544; 54.8%), aged between 50 and 59 years (1,334,195; 27.2%), and classified as having a White ethnic background (3,972,293; 81%). Ethnicity data showed more cases were recorded as Indian or Other ethnic background than any other minority ethnic group captured by the HAT. This is broadly representative of the national population aged 30-90 in England (Sex; females [51.6%] Age; most commonly aged between 50 and 59 years [21.2%]) [38] and ethnicity data for England and Wales (Ethnicity; 86% White, 7.5% Asian, 3.3% Black African/Black Caribbean, 2.2% Mixed and 1% Other ethnic group) (31). Cases by deprivation based on the Index of Multiple Deprivation (IMD) 2019 (where quintile 1 [Q1] is most deprived) [40] indicated more HAT completions among those living in the least deprived areas (Q5 – 707747; 14.4%), but there was representation across the strata (Q4 – 611793, 12.4%; Q3 – 521251, 10.6%; Q2 – 402331, 8.2%; Q1 – 267897, 5.4%).

Calculated heart age was typically estimated to be 1-4 years older than the user's chronological age (in 1668499 of cases, 45%), followed by 5-9 years older (684793, 19.8%) and 1 year younger or the same (545197, 15.6%); irrespective of year of completion.

HAT users often did not enter information on blood pressure or cholesterol. Over half of cases were completed without blood pressure (4898532, 52.9%), over three-quarters were completed without cholesterol (4898532, 76.6%), and approximately half lacked both cholesterol and blood pressure information (4898532, 48.6%).

Open online survey

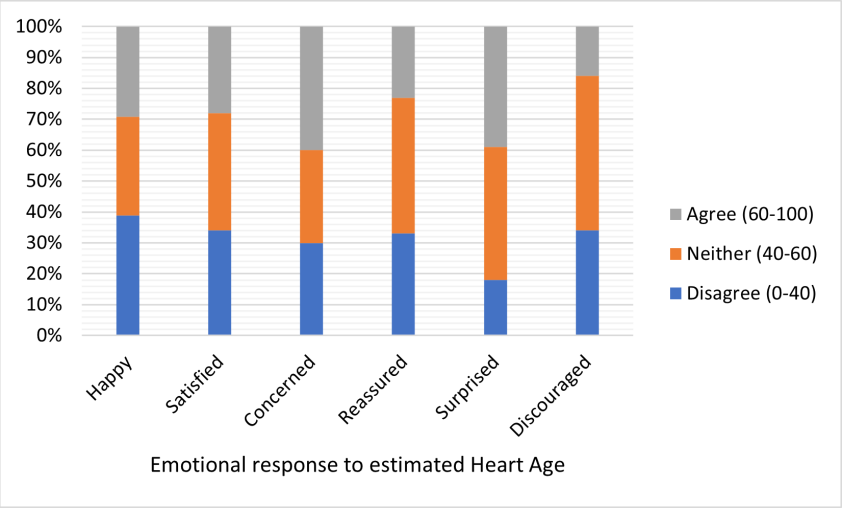
The online survey yielded 819 responses. For those who provided demographic information (n=804, 98.2%), most were women (585, 71.4%), from a White ethnic background (92.2%), and living in areas within the least deprived IMD quintile (Q5, 212, 26.1%) (Table 1). Compared with the HAT user population, a higher proportion of women and those from a White ethnic background took part, but the distributions for age and deprivation were broadly representative of those who typically engage with the test.

Table 1. Characteristics of those who completed the online survey (N=804) compared to typical users of HAT

		Online Survey
Characteristic		N (%)
Age		
	30-35	65 (7.9)
	36-40	69 (8.4)
	41-45	52 (6.3)
	46-50	90 (11)
	51-55	108 (13.2)
	56-60	128 (15.6)
	61-65	121 (14.8)
	66-70	87 (10.6)
	71-74	47 (5.7)
	75+	37 (4.5)
	Missing	15 (1.8)
Sex		
	Male	219 (26.8)
	Female	585 (71.4)
	Missing	15 (1.8)
Ethnic Group		
	White	755 (92.2)
	Indian	13 (1.6)
	Pakistani	4 (0.5)
	Bangladeshi	1 (0.1)
	Other Asian	3 (0.4)
	Black Caribbean	4 (0.5)
	Black African	5 (0.6)
	Chinese	3 (0.4)
	Other ethnic group	13 (1.6)
	Prefer not to answer	3 (0.4)
	Missing	15 (1.8)
Deprivation (IMD Quintiles)		
	1	75 (9.1)
	2	109 (14)
	3	148 (18.1)

	4	170 (20.7)
	5	212 (26.1)
	Missing	99 (12.1)
Last contact with GP		
	In the last week	88 (10.7)
	In the last month	118 (14.4)
	In the last 3 months	150 (18.3)
	In the last 6 months	89 (10.9)
	In the last 12 months	94 (11.5)
	Over 12 months ago	265 (32.4)
	Missing	15 (1.8)
Have a longstanding illness, disability, or disorder		
	Yes	259 (31.7)
	No	527 (64.3)
	Prefer not to answer	18 (2.2)
	Missing	15 (1.8)

Survey respondents understood that an estimated heart age that was older than their chronological age suggested they were at an increased risk of a heart attack or stroke in the future (83.6%, N=819). More respondents reportedly felt concerned or surprised by their estimated heart age than felt happy, satisfied and reassured (see 'agreed' legend; Multimedia Appendix 3: Figure 1).



Multimedia Appendix 3: Figure 3. Participants' emotional response to estimated heart age

Almost two thirds of respondents stated their heart age was higher than they expected (Multimedia Appendix 4). Yet, at least half of respondents reported an increase in their understanding of CVD risk, risk factors and actions that can be taken to reduce risk following completion of the HAT (Multimedia Appendix 4). Similarly, approximately half of respondents also reported increases in confidence related to understanding and control over CVD risk (Multimedia Appendix 4).

Multimedia Appendix 4: Table 2. Expectations, understanding, confidence and actions following completion of the heart age test

Category	Statement	Response	N (%)
Expectations			
	Estimated heart age		
		A lot higher than expected	238 (29.1)
		A little higher than expected	282 (34.4)
		As expected	162 (19.8)
		A little lower than expected	59 (7.2)
		A lot lower than expected	16 (2)
		No expectation	62 (7.6)
Understanding (Following completion of the heart age test, has it helped to understand more about…)			
	Your chance of having a heart attack or stroke		
		Not at all	99 (12.1)
		About the same as before	262 (32)
		A little more	240 (29.3)
		Somewhat more	130 (15.9)
		A lot more	88 (10.7)
	Factors which can increase your chance of having a heart attack or stroke		
		Not at all	67 (8.2)
		About the same as before	338 (41.3)
		A little more	202 (24.7)
		Somewhat more	127 (15.5)
		A lot more	85 (10.4)
	Factors which can reduce your chance of having a heart attack or stroke		
		Not at all	75 (9.2)
		About the same as before	333 (40.7)
		A little more	201 (24.5)
		Somewhat more	127 (15.5)
		A lot more	83 (10.1)
	Actions you could take to reduce your chance of having a heart attack or stroke		
		Not at all	92 (11.2)
		About the same as before	317 (38.7)
		A little more	179 (21.9)
		Somewhat more	140 (17.1)
		A lot more	91 (11.1)
Confidence (Following completion of the heart age test, how confident are you…)			
	Understand what risk factors could increase your chance of having a heart attack or stroke		
		Not at all	32 (3.9)
		About the same as before	334 (40.8)
		A little more	93 (11.4)
		Somewhat more	130 (15.9)
		A lot more	230 (28.1)
	Understand how to change your chance of having a heart attack or stroke		
		Not at all	48 (5.9)

		About the same as before	315 (38.5)
		A little more	114 (13.9)
		Somewhat more	150 (18.3)
		A lot more	192 (23.4)
	Have control over your chance of having a heart attack or stroke		
		Not at all	59 (7.2)
		About the same as before	317 (38.7)
		A little more	123 (15)
		Somewhat more	168 (20.5)
		A lot more	152 (18.6)
	Can reduce your chance of having a heart attack or stroke		
		Not at all	48 (5.9)
		About the same as before	311 (38)
		A little more	132 (16.1)
		Somewhat more	165 (20.1)
		A lot more	163 (19.9)
	Have the skills or support you need to reduce your chance of having a heart attack or stroke		
		Not at all	75 (9.2)
		About the same as before	327 (39.9)
		A little more	119 (14.5)
		Somewhat more	164 (20)
		A lot more	134 (16.4)
Actions			
	Having found out your estimated heart age, do you intend to take any of the following actions…		
		Blood pressure check by a GP, Nurse or Pharmacist	127 (15.5)
		Check my blood pressure myself (home blood pressure monitor)	211 (25.8)
		Book an appointment to get my cholesterol levels checked	236 (28.8)
		Set a goal to attempt to quit smoking	17 (2.1)
		Set a goal to lose weight	374 (45.7)
		Set a goal to eat more healthily	283 (34.6)
		Set a goal to get more active (i.e., going for a walk a day)	302 (36.9)
		Look for more information about heart health	111 (13.6)
		I do not intend to take any action	146 (17.8)
		Something else	107 (13.1)

Most respondents suggested they intended to take some action following completion of the test (Multimedia Appendix 4). Intentions to set a goal to lose weight (374, 45.7%), followed by a goal to increase physical activity (302, 36.9%) and eat more healthily (283, 34.6%) were most commonly selected by respondents. The most common reason for not intending to take action was that their

heart was healthy for their age and 'other' (e.g., COVID-19 restrictions, continuing healthy behaviour adopted prior to completion of the test).

Acceptability of attending a preventative health assessment (i.e., an NHS Health Check) was high following completion of the test (624, 76.2%). Most respondents suggested they would probably (264, 32.2%) or definitely (375, 45.8%) engage with the test again in the future to assess their heart health. Those who suggested they would probably or definitely not engage with the test again in the future (144, 17.6%), reported that their estimated heart age was a lot (59, 41%) or a little higher (44, 31%) than they expected.

Follow-up interviews

Semi-structured, telephone interviews were conducted with a sub-sample of survey respondents (n=33, mean duration 21±-6 minutes). Most participants were aged 51-60 years (10, 34%), female (19, 58%), from a White ethnic background (27, 82%) and living in areas nationally ranked in the 50% least deprived (19, 58%) (Table 3). The average duration between completion of the test and the interview was eight days (±3 days, range 2-13 days).

Table 3. Interview participant characteristics (N=33)

Characteristic		N (%)
Sex		
	Male	14 (42)
	Female	19 (58)
Age (years)		
	30-35	1 (3)
	36-40	5 (15)
	41-45	4 (12)
	46-50	2 (6)
	51-55	5 (15)
	56-60	6 (19)
	61-65	4 (12)
	66-70	3 (9)
	71-75	2 (6)
	75+	1 (3)
Ethnic Group		
	White	27 (82)
	Ethnic minority [a]	6 (18)
Deprivation		
	Most Deprived (IMD 1-5) [b]	14 (42)
	Least Deprived (IMD 6-10) [b]	19 (58)
Last contact with GP		
	In the last week	4 (12)
	In the last month	5 (15)
	In the last 3 months	8 (24)

	In the last 6 months	3 (9)
	In the last 12 months	4 (12)
	Over 12 months ago	9 (28)
Have a longstanding illness, disability or disorder		
	Yes	15 (45)
	No	18 (55)

[a] Representative of those from a Chinese, Indian, Black Caribbean and 'other' ethnic background; [b] IMD - Index of Multiple Deprivation where 1=Most deprived, and 10=Least deprived

Analysis of interview data produced four themes: 'emotional response to estimated heart age', 'perceived understanding of CVD risk', 'perception of the heart age test', and 'making a change?'. Each theme is examined in turn and evidenced by interview transcripts (e.g., each extract is labelled to indicate participant number (PX), age, sex (M=Male, F=Female), IMD quintile (QX) and ethnicity (WB=White, EM=ethnic minority).

Emotional response to estimated heart age

Following completion of the HAT, many participants were *"a little bit surprised"* when their result did not equate to expectations *"because [they were] really active, [they] do a lot of exercise"* (P25, 36-40y, F, Q5, W) and *"because [their] blood pressure is good, [their] weight is good"* (P24, 41-45y, F, Q5, W). Some of these participants felt frustrated that they "*didn't see [their] biological age"* (P32, 51-55y, M, Q2, EM) as it did not *"fit with [their] experience of most people [their] age"* (P7, 56-60y, F, Q4, W). Others considered the estimated heart age to be a *"real wake-up call"* (P21, 66-70y, F, Q2, W) and *"a bit of a boost to say actually 'yeah I do need to understand these levels'… I could do better with my own lifestyle"* (P9, 30-35y, M, Q3, W).

Some participants were *"pleasantly surprised that [they weren't] more unhealthy"* (P4, 36-40y, F, Q5, W). This was due to recognition of a lack of engagement in healthy behaviours: *"I don't do much exercise as I used to, or I would like to"* (P12, 41-45y, M, Q3, W). Those that received an estimated heart age equal to or lower than their chronological age found their result "w*as actually quite pleasing"* (P10, 61-65y, M, Q3, W) and it *"reassured [them that] 'oh there is a point to [a healthy lifestyle]'"* (P11, 71-75y, M, Q5, W) choosing to *"los[e] some weight"* (P5, 46-50y, M, Q5, W) prior to taking the test.

In summary, participants reported both positive and negative emotional responses following completion of the HAT, particularly when their result did not meet prior expectations. For some, the test served as a wake-up call and encouraged them to re-evaluate their behaviour.

Perceived understanding of CVD risk

Participants perceived to have a good understanding of their estimated heart age, with some suggesting the test indicated their heart was older than their chronological age: *"…basically, I am a 79-year-old person"* (P20, 66-70y, M, Q2, W). Those with an estimated heart age older than their chronological age understood that "*there is obviously a little bit more [they] could do to look after [themselves]"* (P25, 36-40y, F, Q5, W), whilst those with an estimated heart age equal to their chronological age thought their *"behaviour, what [they are] eating, doing, isn't making [their] heart necessarily any worse"* (P4, 36-40y, F, Q5, W).

Understanding of CVD risk was also perceived to be high, as participants suggested they were already aware of factors that can increase your risk of a heart attack or stroke as a result of information on *"social media and previous knowledge"* (P15, 66-70y, F, Q4, W) or from "*family members that have had issues with their hearts"* (P9, 30-35y, M, Q3, W).

Results from the HAT also provide users with their CVD event-free survival age (Multimedia Appendix 1; presented in HAT as 'On average, someone like you can expect to live to the age of XX without having a heart attack or stroke'). A small number of participants struggled to interpret this information: *"I was predicted to die at 77"* (P5, 46-50y, M, Q5, W); *"from age 53, I should be expecting to have a heart attack. That is how I read it"* (P32, 51-55y, M, Q2, EM). Others found it difficult to determine which factors were increasing their estimated heart age: *"I don't know whether it's the cholesterol figure I put in, that is the only thing I can think of at the minute"* (P8, 56-60y, F, Q4, W). This was concerning for a small number of participants and as a result the interviewer had to explain the result to provide some reassurance.

In summary, most interview participants perceived that they had a good understanding of estimated heart age and CVD risk prior to completing HAT due to information obtained from social media and personal experience. A minority struggled to interpret CVD event-free survival age, presented in HAT, which led to some concern and confusion about their results and their CVD risk.

Perception of the heart age test

Most participants thought the HAT was *"easy to use and interesting"* (P2, 51-55y, F, Q2, W) or *"very clear and concise"* (P9, 30-35y, M, Q3, W). The HAT was perceived to be "*quite informative"* (P14, 51-55y, F, Q1, W) and would be helpful to those who need to improve their health behaviour "*like my mum"* (P6, 51-55y, F, Q5, W).

However, most comments referred to the fact that heart age was estimated from limited information: *"I don't think it had much to go on"* (P5, 46-50y, M, Q5, W). Participants expected to be asked about other factors such as alcohol: *"[it] didn't ask me like alcohol intake... that sort of surprise[d] me"* (P10, 61-65y, M, Q3, W); or physical activity: *"I don't remember there being an exercise question"* (P8, 56-60y, F, Q4, W). Others questioned the accuracy of the test when an individual is unable to report their blood pressure and cholesterol information: *"with those answers [BP and cholesterol] it may have been more precise, or maybe a bit more accurate"* (P23, 61-65y, F, Q2, EM); *"they are fairly important measurements to put in aren't they?"* (P4, 36-40y, F, Q5, W). For this reason, a small proportion of participants whose estimated heart age was older than their chronological age chose to "*discount the whole thing because you just don't believe it, it's how it is, isn't it. They have got it wrong"* (P11, 71-75y, M, Q5, W).

Nevertheless, some participants had already recommended the test when interviewed: *"my son is 33 and I said to him you need to be doing this now. My niece, I rang her and told her and my sister"* (P21, 66-70y, F, Q2, W). Others suggested they would recommend the test *"to some, not to all, it probably depends on where I think they are at, at the time"* (P30, 41-45y, F, Q4, EM). This was mostly due to feeling it is not their *"job [to discuss health behaviour choices with someone] …It is quite a delicate subject"* (P16, 51-55y, M, Q4, W).

In summary, participants liked the simplicity of the test, but some questioned its accuracy due to the amount of information required and where they were unable to provide information about their blood

pressure and cholesterol. Despite this, most would or had already recommended the HAT to others. This implies a perceived benefit regardless of their reservations about HAT's accuracy.

Making a change?

Following completion of the HAT, most participants suggested the test prompted them to consider *"doing more exercises"* (P6, 51-55y, F, Q5, W), *"calorie intake"* (P25, 36-40y, F, Q5, W) and weight loss "*certainly 3[kgs]"* (P10, 61-65y, M, Q3, W). Participants also suggested the HAT could be a catalyst to engage with primary care, for example either *"just have a check-up"* (P9, 30-35y, M, Q4, W) or *"to find out [what their cholesterol and blood pressure numbers were]"* (P30, 41-45y, F, Q4, EM). Yet, some questioned *"whether [their] motivation [would] persist"* (P1, 36-40y, M, Q4, W) once the burden of the coronavirus pandemic became more manageable for GPs and they could subsequently book a check-up.

Some participants reported that they had already made changes to their health behaviour including "*doing more regular exercise."* (P3, 41-45y, F, Q1, W) and researching "*about food portions…checking calories, how much do you need"* (P27, 36-40y, F, Q5, EM). Only one participant asked a health professional if they could have their cholesterol and blood pressure checked at a routine blood test for a pre-existing condition and were surprised to learn their blood pressure was high: *"the doctor rang me…he said because you have got a rheumatoid flame up at the moment, that would put your blood pressure up…if I hadn't done that survey I wouldn't have had a clue"* (P21, 66-70y, F, Q2, W). This low level of follow-up among users may be explained by the coronavirus pandemic, as participants felt it was *"probably not the right time"* (P30, 41-45y, F, Q4, EM) to ask their GP for follow-up tests. Another participant suggested the HAT had encouraged them to reconsider their smoking habit:

> It brought it home a bit more to me… it was just the test that really said to me… 'Hang on [name], do you have to have a cigarette now' and that has been 'no', so it is just breaking habits (P20, 66-70y, M, Q2, W)

Changes to behaviour were largely reported to be a result of completing the HAT and *"because of [their] family history"* (P24, 41-45y, F, Q5, W) or influences from family members: *"my little lad…to hear him say 'you know mum that has put so many years on your [heart] which means you are going to lose those years'. That was… a big factor hearing my little boy say that"* (P3, 41-45y, F, Q1, W).

Those without intentions to change their behaviour suggested it was because they didn't "*feel there are massive life changes to be made as a result of what was in the test"* (P1, 36-40y, M, Q4, W) or because *"[their] heart age [was] only slightly above [their] real age"* (P22, 56-60y, M, Q3, EM). However, participants stated that they would attend an NHS Health Check following the completion of the HAT as *"it would be nice to understand more about …the actual health of [their] heart"* (P26, 36-40y, F, Q5, W).

In summary, most participants had intentions to or had already made changes to their health behaviour following completion of the HAT. Those that had already taken action to improve their health prior to completing the test suggested it had encouraged them to maintain those changes. Although behavioural intentions and changes were reportedly due to the HAT, most participants had already made changes to their health behaviour prior to completing HAT which indicates that

participants were already invested in improving their health.

Discussion

Principal results and comparison to prior work

To our knowledge, there is limited evidence of the effect of England's HAT from a sample of users. With almost five million completions up to June 2020, the findings suggest there is considerable public interest in heart health. Overall, users who engaged with the test were most commonly male, aged between 50 and 59 years, classified as having a White ethnic background and living in least deprived areas; similar to a previous descriptive study published in 2016 [24]. This contrasts with other heart age calculators, that have typically reported higher proportions of female users [27,31]. This may be explained by a campaign in 2018 which led to a surge in HAT engagement particularly from men.

Analysis of the online survey and interview data suggested that the HAT provoked a negative emotional response when the score did not meet prior expectations, reflective of findings reported elsewhere [31]. Participants also suggested they understood the significance of an estimated heart age being higher than their chronological age, self-reported at least some improvements to understanding of their CVD risk and confidence in understanding and control of their CVD risk. Compared with percentage risk scores, there is evidence that heart age is more emotionally impactful, and improves risk perception and recall [10–12,15–22]. Yet, CVD event-free survival age (presented in HAT - see Multimedia Appendix 1) was reportedly difficult to interpret, which led to some concern and confusion about why their estimated heart age was higher than their chronological age for some participants. There is little evidence of the impact of CVD event-free survival age, but poor understanding from both patients and practitioners has been reported elsewhere [5,41], suggesting the need for greater caution and clarity when presenting risk information in this format.

Participants questioned the accuracy of the HAT, largely due to the small amount of information required from which heart age was estimated and the implications of not knowing their BP or cholesterol to inform this estimate. Concerns that heart age can overestimate CVD risk are well reported [19,27,31,34,42] and have led to calls for caution in its application [17,34]. Nevertheless, most participants suggested they would or already had recommended the HAT to others, would engage with the test again in the future, would be more likely to take up the offer of an NHS Health Check, self-reported that they had made or intended to change their health behaviour (i.e., lose weight, be more active and eat more healthily) or were encouraged and motivated by the test to maintain the changes to their health behaviour.

Researchers have suggested that estimated heart age can motivate individuals to make changes to their health behaviour [10,19–22,31,43,44] and prompt health behaviour change and clinical checks [20,31]. As with Australia's heart age calculator, participants most commonly self-reported changes or intentions to improve their diet, lose weight and be more active following completion of the HAT [31]. Yet, a recent systemic review that explored the effects of heart age interventions concluded that there is limited evidence to suggest that heart age alone can lead to positive behavioural outcomes [13]. In this study, participants reported some engagement in healthy behaviours prior to completing the HAT and their motivation to reduce their CVD risk also resulted from other factors including supportive family and friends and a family history of CVD. Therefore, heart age calculators may be one method that can used in combination with other behavioural strategies to encourage individuals to

re-evaluate their current health behaviour and to increase intentions to improve their heart health. The longer-term outcomes from HAT are yet to be explored.

Strengths and limitations

To our knowledge, this is the first study of England's HAT to explore user experiences and intentions to action. Strengths of this study include the multiple data sources which allowed for cross-validation of findings and participant experiences. The survey sample differed in some respect but still represented the socio-demographic range of the population of England, with participants from various age, sex, ethnic background and deprivation levels. Interview participants were purposively sampled to be representative of the typical profile of HAT users, with over-representation of those from ethnic minority backgrounds to ensure a range of views and experiences were captured. A sub-sample of interviews were independently coded by two qualitative researchers which provided a robust examination of the data.

Several limitations are acknowledged. First, deprivation could not be determined for almost half of HAT users (48.8%). Users may have completed the HAT with fictitious data, and those with no postcode could reside outside of England, which could undermine assertions about the HAT user population. Second, the self-selecting sample introduces a degree of bias to be reflective of those who typically engage with digital self-checking tests (i.e., ecologically valid). This may be arguably greater in the interview sample, representing those who are more knowledgeable and positive about their health. However, both positive and negative views and experiences were described by participants which suggests this had a limited influence on the findings. Third, to be representative of typical HAT users, fewer older participants were recruited for follow-up interviews. Due to their age, these individuals are predisposed to an increased CVD risk which may be likely to affect their perception of the test and future behavioural intentions. Their limited inclusion in the study may have influenced the findings. Fourth, there is under-representation of those living in the most deprived areas. While this is representative of those who typically engage with the HAT, it limits the conclusions that can be drawn in this sample of individuals. Further work is needed to understand the impact of heart age on those most deprived. Fifth, many participants self-reported that their intentions to or actual changes to their health behaviour resulted from completing the HAT. However, as most participants reported at least some engagement in healthy behaviours prior to completing the test these outcomes cannot be attributed to the HAT alone. Therefore, participant's future engagement in healthy behaviours cannot be attributed to competing the HAT alone. Future research could explore the impact of HAT on those not currently engaged in risk reducing behaviours. Sixth, data were collected during a period of national lockdown (England, Jan-Mar 2021) which may have impacted on participant responses (i.e., self-reported intentions to or actual behaviour change, access to health care services). This may have led to an under or overinflation of self-reported intentions to change behaviour and reduced access to health care services.

Future directions

Completion of England's HAT elicited a negative emotional response when the result did not match prior risk perception. Whilst this served as a wake-up call for most, the credibility of the test was questioned by all participants and subsequently dismissed by some. Therefore, adequate signposting to support and more information about how estimated heart age is calculated is needed to support

users who may feel confused or concerned about their result. Clearer information about the accuracy of the result is also warranted, especially if the user was unable to provide physiological risk factor information (i.e., BP, cholesterol).

Most participants reportedly had a good understanding of the meaning of a higher estimated heart age, suggesting that heart age calculators may be a good way to improve population understanding of CVD risk. However, given the misinterpretation of CVD event-free survival age, greater caution and clarity is needed when presenting risk information in this format. Participants also self-reported changes to their health behaviour and, intentions to make healthier behaviour choices and engage with primary care services (i.e., arrange a blood pressure or cholesterol check) upon completion of the test. Yet, it could not be determined if these participants were estimated to have a heart age that was older than their chronological age as few participants shared their result during interview. Notwithstanding, web-based tests like HAT may be a good way to encourage individuals to manage their own health by self-checking their heart health. Where clinically appropriate some users reported intending to see a health care professional for blood pressure and or lipid assessments. This could support a range of incentives recently introduced in England to enable individuals over the age of 40 to get their blood pressure checked.

The volume of HAT completions reported here (almost 5 million from February 2015 to June 2020) suggests considerable public interest in heart health. However, there was a pattern of under-representation of those living in the most deprived areas here that suggest a need to further explore the extent of inequalities; both in reach/access, but also in how the potential benefits are distributed across the socio-economic strata.

Conclusions

With almost five million completions up to June 2020, findings from our evaluation of England's HAT in a subgroup of users suggests there is considerable public interest in heart health. The test was shown to elicit a more negative emotional response when estimated heart age did not equate to prior risk perceptions, reportedly led to increased understanding of a higher estimated heart age, and at least some improvements to understanding of CVD risk and confidence in understanding and control of CVD risk. Despite concerns resulting from the limited information needed to complete the test or missing physiological risk factor information (i.e., BP, cholesterol), participants suggested they would or had already recommended the test to others, would use it again in the future to check their heart health, would be more likely to take up the offer of an NHS Health Check, and self-reported that they had made or intended to make changes to their health behaviour or felt encouraged and motivated by the HAT to continue changes to their health behaviour. Yet, many participants self-reported at least some engagement in healthy behaviours prior to completing the test therefore some of these outcomes cannot be attributed to the HAT alone. A web-based self-checking test like England's HAT may be a good way to raise awareness about CVD risk, encourage individuals to self-check their heart health and consider healthier behaviour choices in combination with other behavioural strategies. However, more adequate signposting to support and information about how estimated heart age is calculated and presentation of CVD event-free survival age should be considered to avoid user confusion and improve satisfaction.

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Data Availability

The data sets generated during and/or analysed during the current study are not publicly available as consent was not requested by participants during data collection.

Conflicts of interest

The heart age test was jointly developed by Public Health England, the British Heart Foundation, the Joint British Societies and NHS Digital. The funder (Public Health England) collaborated on the study design and the write-up of this paper.

Abbreviations

CVD – cardiovascular disease

HAT – Heart age test

IMD - Index of multiple deprivation

LSOA - Lower layer super output areas

NHS – National Health Service, UK

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