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Patient perceptions of three-dimensional (3D) surface imaging technology and traditional methods used to assess anthropometry.

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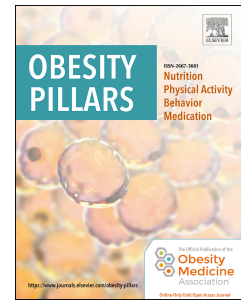
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Patient perceptions of three-dimensional (3D) surface imaging technology and traditional methods used to assess anthropometry

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Patient perceptions of three-dimensional (3D) surface imaging technology and traditional methods used to assess anthropometry

Participants and Method

49 Participants completed an online questionnaire about their past and present use of body size measurements

26 participants attended the laboratory for a semi-structured interview

This included traditional body size and novel 3D surface imaging measurements

Results

- 3D-surface imaging appeared to be acceptable to patients as a method for anthropometric measurements
- Less 'hands-on' anthropometric measures may reduce anxiety and improve attrition rates in some populations.
- However, data from the 3D surface imaging was complex and confusing for some participants
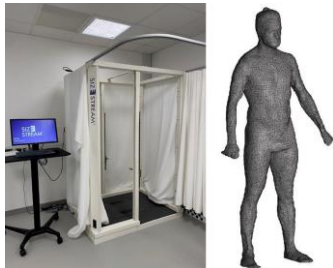
Themes

1. Use of technology
2. Participant experience, expectations and perceptions
3. Perceived benefits and uses

Conclusion

- 3D surface imaging appeared to be an acceptable method for anthropometric measurements, which may reduce anxiety and improve attrition in some populations
- Further work is required to understand scalability, the role and implications of this technology in weight management practice

"Patient perceptions of three-dimensional (3D) surface imaging technology and traditional methods used to assess anthropometry."

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Abstract

Background: Obesity and overweight are commonplace, yet attrition rates in weight management clinics are high. Traditional methods of body measurement may be a deterrent due to invasive and time-consuming measurements and negative experiences of how data are presented back to individuals. Emerging new technologies, such as three-dimensional (3D) surface imaging technology, might provide a suitable alternative. This study aimed to understand acceptability of traditional and 3D surface imaging-based body measures, and whether perceptions differ between population groups.

Methods: This study used a questionnaire to explore body image, body measurement and shape, followed by a qualitative semi-structured interview and first-hand experience of traditional and 3D surface imaging-based body measures.

Results: 49 participants responded to the questionnaire and 26 participants attended for the body measurements and interview over a 2-month period. There were 3 main themes from the qualitative data 1) Use of technology, 2) Participant experience, expectations and perceptions and 3) Perceived benefits and uses.

Conclusion: From this study, 3D-surface imaging appeared to be acceptable to patients as a method for anthropometric measurements, which may reduce anxiety and improve attrition rates in some populations. Further work is required to understand the scalability, and the role and implications of these technologies in weight management practice. (University Research Ethics Committee reference number ER41719941).

1   Introduction/background

1   Obesity is a widespread, chronic, complex disease associated with excess fat mass, and

2   contributes to many weight related comorbidities such as cancer, heart disease, stroke,

3   depression and premature mortality [1]. Obesity incurs a huge cost both financially, societally,

4   and personally to those living with obesity.

5   Overweight and obesity are traditionally assessed using the body mass index (BMI) which

6   gives a ratio of a person's weight to their height squared [2]. BMI provides a measure of

7   relative obesity and stratifies individuals into categories (underweight, normal weight,

8   overweight and obese) according to World Health Organization (WHO) guidelines [3] [4]

9   Whilst this is important clinically and on a population level, BMI is strongly contested as a

10 useful measure for individuals as it does not accurately reflect variations in body composition,

11 weight distribution, and other features of human morphology [5] [6] [7] [8] which can lead

12 to misclassification of individuals [9].

13 Weight management services traditionally involve a holistic assessment of the individual,

14 including an understanding of their body size and shape, and how this relates to their current

15 weight status. However, many service users can be uncomfortable with being weighed or

16 measured [10] for several reasons, such as invasion of personal space and body measures

17 reflecting an unflattering personal attribute [11]. It is hypothesised that this may deter

18 individuals from attending weight management services or contribute to high attrition rates.

19 In addition, weight stigma is experienced from healthcare professionals (HCPs) and avoiding

20 being weighed is a primary reason why women avoid attending appointments [12]. Reasons

21 given for women refusing to be weighed can range from shame and embarrassment, to

22 concerns about discrimination [12]. Therefore, identifying interventions and alternative ways

23 of measuring the human body that are non-stigmatising could reduce the negative impact of

24 body measurement in healthcare.

25 Emerging new technologies for assessing human morphology, such as three-dimensional (3D)

26 surface imaging technology, could provide an attractive alternative to traditional manual

27 anthropometric techniques [13]. Modern 3D surface imaging systems, acquire point cloud

28 data that explicitly capture surface topography, which can provide detailed and accurate

29 external dimensions and shape characteristics of the human body, such as curvature and

30 partial volumes [14] [15]. Surface features extracted from this 3D imaging data can be used

31 to characterise individuals according to their shape [16], as well as their size, to a higher

32 degree of precision and complexity than existing manual methods [17] [18]. Several imaging

33 techniques can be used to create full body geometries, with a range of commercial 3D imaging

34 systems currently available [19] [20] [21] [22], each varying in their underlying technologies,

35 cost, functionality and accuracy. Examples of the most common imaging techniques are

36 presented in Table 1.

37 *Table 1. Overview of different techniques and commercially available 3D imaging systems for body measurement.*

Imaging technique	Brands/Models	System type	Cost (USD$)	Accuracy	Scan duration
Laser line [23] [24]	Cyberware WBX Vitrionics Vitus Smart	-	~37,000 - 240,000	< 2 mm 27 points/cm^3	~10 - 15 secs
Stereo Photogrammetry [25] [26]	Cranfield Vectra 3dMDbody e.g. Flex8	Passive Hybrid	~190,000	0.2 mm < 0.2 mm	~2 - 8 msecs ~1.5 msecs
Structured light [27][28]	Artec Eva/Spider TC2 KX-16 SizeStream	Blue light Infrared Infrared	~10,000 - 20,000	0.1/0.05 mm 1 mm 1 mm	161/8 fps 3 secs 6 secs

Depth sensor [29] [30] [31]	Microsoft Kinect V2 Intel Realsense D435	Time of flight Stereoscopic	~200/per device (~1000/system)	< 6.5 mm > 6.5 mm	< 10 secs (single camera)/ ~0.8 secs (multi camera)

38

39　Typically, 3D surface imaging techniques utilise some form of projected light to acquire

40　external body shape data - laser line, infrared or blue light – which capture external

41　dimensions of the human body quickly (<10 seconds), and without the need to touch the

42　individual or expose them to harmful radiation that is associated with imaging modalities such

43　as computed tomography (CT). Though 3D surface imaging technology was previously

44　expensive, increased use of 3D surface imaging in entertainment, fashion, ergonomics, and

45　health has bolstered the market, leading to reduced prices and greater accessibility [32].

46　Recent literature has suggested that 3D surface imaging technology can be a potential

47　method for estimating body composition [33] [19] [34] [35] [36] [37] [38] [39] [40] [41] [42]

48　[43] and can provide precise, reliable, accurate [44] and meaningful information about the

49　quantity and distribution of fat throughout the body [45]. Moreover, commercially available

50　3D body scanning has been shown to provide valid estimations of total body volume and

51　relative body fat mass in comparison to air displacement plethysmography [46] and accurate

52　estimations of fat mass, fat free mass and % body fat when compared to a 4-component

53　model (Dual-energy x-ray absorptiometry) [47]. However, like other anthropometry-based

54　estimation techniques, body composition prediction using 3D imaging is a doubly indirect

55　method relying on the use of regression algorithms [48] , which are dependent upon the

56　accuracy of the raw 3D imaging data. An assessment of commercially available scanners

57　highlighted variability in the validity of, and proportional bias for all scanners that were

58　assessed [47]. Acknowledging its limitations, 3D imaging provides the possibility of quick,

59   contactless, ionizing radiation-free body composition measurement without the need for a

60   technician suitable for regular use [34] [42]. It is possible that this novel technology, could

61   provide greater granularity to anthropometric and morphological measures which may

62   prevent the of misclassification of overweight and obesity and provide an alternative way to

63   measure changes in weight, which could appeal to some individuals, where physical touch is

64   culturally, practically, or socially unacceptable.

65   However, attitudes towards this technology as an alternative anthropometric tool for use

66   within healthcare and weight management are currently unclear. The prevalence of

67   individuals that suffer from issues relating to body image and body dysmorphic disorder (BDD)

68   [49] is increasing and has potentially accelerated due to the emergence of social media [50].

69   Therefore, the need for sensitivity when collecting body measurement data from individuals

70   and presenting their images back to them is paramount, due to the potential risks of causing

71   a negative psychological response pertaining to body image issues.

72   The aim of this study was to understand acceptability of traditional and 3D surface imaging-

73   based body measures, and whether perceptions of these techniques differ between

74   population groups.

75   To achieve this aim, we sought to answer the following research questions:

76   1) What are the current methods and strategies employed by individuals to monitor their

77   body weight and/or composition?

78   2) What are the key drivers behind the strategies employed to monitor their body weight

79   and/or composition?

80   3) How does the emotive response differ between established methods of assessing body

81   morphology and does the use of novel 3D surface imaging technology produce a different

82   response?

2   Methods

2.1   Participants

85   The primary outcome in this study was subjective perceptions of acceptability towards

86   traditional and novel methods for assessing body shape. The inclusion criteria for this study

87   were that participants needed to be aged 18 years or above and be able to stand unaided for

88   approximately five minutes to enable them to complete the 3D imaging procedure.

89   Participants also needed experience of possible weight loss strategies; however, they did not

90   need to be actively trying to lose weight at the time of the study. Body weight metrics were

91   not an inclusion criterion for this study. Participants were recruited via social media, e-mail,

92   word-of-mouth and posters. Additional face-to-face promotional events were also held in

93   public venues including the city library, shopping centre and university buildings.

94   Participants were given a detailed participant information sheet before the study

95   commencement, detailing the study protocol and providing information about the voluntary

96   nature of their input, assurance of data anonymisation, and maintenance of confidentiality.

97   Consent was confirmed prior to completing the questionnaire and the on-site interview.

98   Participants were free to withdraw from the study at any point during the process although

99   any data captured up the point of withdrawal would be stored securely and used in an

100   anonymised format. Participants were offered a £20 shopping voucher as a thank you for

101 attending the session. Recruitment methods signposted potential participants to a short

102 online questionnaire via Qualtrics.

103 Ethical consent was gained via a robust peer-reviewed University research ethics process at

104 Sheffield Hallam University (REC number ER41719941).

2.2 Measures

106 The questionnaire collated basic demographic information such as age, gender, postcode and

107 education status and also included the Cosmetic Procedure Screening questionnaire (COPS)

108 for BDD [51]. Postcode data allowed researchers to calculate the Index of Multiple

109 Deprivation (IMD) The questionnaire aimed to determine how a person engages with their

110 own self-image, whether and how they track their own body size and shape, and what

111 methods and strategies they currently employ, or have previously employed if trying to alter

112 their own self-image (through weight loss or physical training for example) and to monitor

113 the physical aspects of their body such as shape and size (e.g., weighing scales, tape measure,

114 photographs etc..) (see questionnaire in supplementary materials).

115 Participants were eligible for the second part of the study if they were over 18 years of age

116 and able to stand unaided for five minutes or more (necessary during 3D surface imaging).

117 Participants should have tried to manage their weight in the past (for any reason) but did not

118 need to be actively trying to lose weight at the time of the study. Respondents who screened

119 positively for body dysmorphia (a screening tool score higher than 40) [51] were not invited

120 to further follow-up interview sessions as the researchers felt it was unethical to subject those

121 at potential risk of living with body dysmorphia to further detailed scrutiny of their body shape

122 and size.

123   There were 53 responses to the questionnaire, but after removal of duplicates, there were 49

124   unique respondents. Twenty-six participants completed the follow-up interview and

125   laboratory visit (Sheffield, UK). Participants were asked to attend the clinic with some form-

126   fitting clothes. Cycling shorts and a vest top were provided by the research team if necessary.

127   The interview was a semi-structured session with two parts which took part face-to-face in

128   the body morphology laboratory at a time that was convenient for the participant. Initially,

129   the interviewer explored themes arising from the initial questionnaire. The interview

130   explored their current and previous use of body measurements, perceptions of 'future

131   technologies' for weight management, and gathered initial ideas and impressions of 3D

132   surface imaging as a potential technology (see semi structured interview in supplementary

133   materials).

134   After the first stage of the interview each participant had traditional body morphology

135   measures taken, and a 3D surface image. The traditional measures included: a Leicester

136   height stadiometer (Marsden, UK), digital weight scales (Conair, UK), hip and waist girth

137   measures using a basic anthropometric tape measure (Lufkin Executive Thinline 2m,

138   W606PM). A Size Stream SS20 3D surface imaging device (Size Stream, Cary, NC, USA), was

139   used to obtain 3D surface images of participants (Figure 1).

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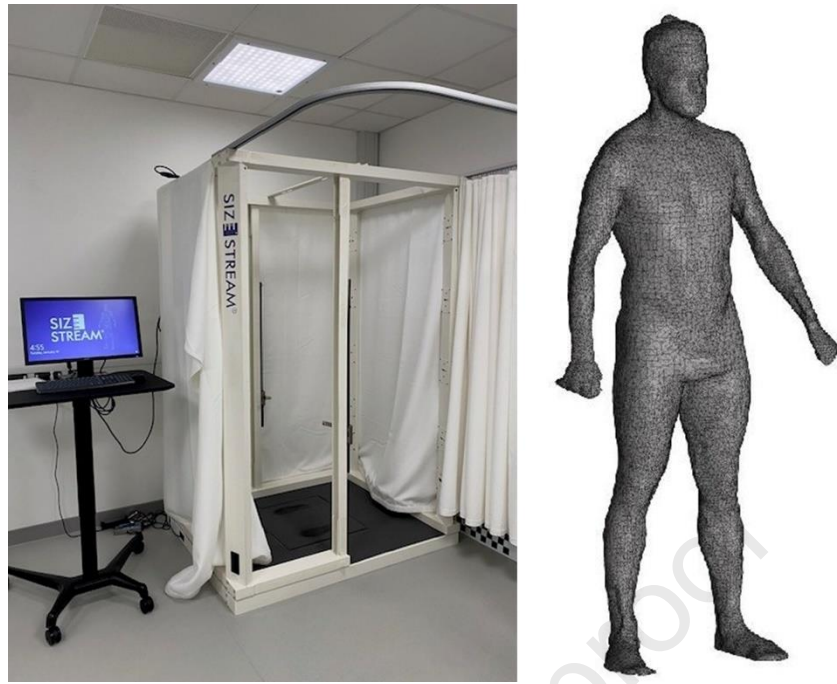
Figure 1. Image of 3D imaging device used and example of extracted data.

142 Prior to the 3D surface image scan, participants were provided with appropriately sized, form

143 fitting clothing. During the scanning procedure, participants were asked to adopt a

144 standardised pose, as demonstrated in the example of extracted data in Figure 1, and hold

145 their breath for approximately 10 seconds.

146 Data was shared with all participants at the interview, and a standard 3D model was shared

147 with all participants to explain the output from a 3D surface imaging device. A copy of their

148 individual participant data was provided to any participant who requested it. Following the

149 body measurement session, the second stage interview explored the same themes as in the

150 first stage with the objective of exploring ways in which initial perceptions of participants

151 were changed or confirmed by experiencing the different measurement procedures and any

152 new perceptions or ideas that were generated.

153 Each participant's data was anonymised using a simple naming convention including

154 participant ID, date created, etc. and encrypted in a Microsoft Excel file.

155 The interviews were voice-recorded and transcribed using Otter.ai transcription software

156 [52].

157 ### 2.3 Data analysis

158 The research team immersed themselves in the data by listening to the audio interviews and

159 reading and editing the transcripts (AC) produced by Otter.ai.

160 The data was analysed by the research team (LN, MT, SM, SC) using the qualitative framework

161 analysis approach [53][54]. This approach was developed in an applied research context to

162 systematically manage qualitative data to identify potential for actionable outcomes by

163 providing transparent results and conclusions that can be related to the original data.

164 ### 2.4 Data synthesis

165 Qualitative analysis was undertaken using framework analysis [55]; Data was analysed

166 manually in the following five stages:

167   I. familiarising (reading and rereading data transcripts)

168   II. identifying a thematic framework (the theory changes thematic framework

169   informed the analysis)

170   III. indexing (entered short summaries into the coding frame)

171   IV. charting (entering themes into a matrix using columns and rows for

172   summarised data)

173   V.   mapping and interpretation (comparing data excerpts, searching for

174   patterns, and seeking explanations for patterns in the data).

175   Following Gale et al. (2013) quotes were extracted from the transcripts to populate the

176   framework [53].

177   The data is reported using a Standards for Reporting Qualitative Research (SRQR) using the

178   consolidated criteria for reporting qualitative studies (COREQ), based on a 32-item checklist

179   [54].

3   Results

3.1   Part 1: Online Questionnaire

182   After removal of duplicates and null responses, 49 respondents completed the initial online

183   questionnaire. The demographic breakdown of respondents is shown in Table 2.

184   *Table 2. Demographic breakdown of respondents to online questionnaire and interview.*

Sex – n (%)	In questionnaire (n= 49)	In interviews (n=26)
Male	18 (37%)	13 (50%)
Female	31 (63%)	13 (50%)
Age (years) - n (%)		
18-35	21 (43%)	10 (38%)
36-45	3 (6%)	1 (4%)
46-55	8 (16%)	5 (19%)
56-65	12 (25%)	7(27%)
65+	5 (10%)	3 (12%)
Race/Ethnicity – n (%)		
Asian / Asian British - Bangladeshi	1 (2%)	1 (4%)
Asian / Asian British - Pakistani	1 (2%)	0 (0%)
Asian / Asian British - Indian	3 (6%)	0 (0%)
Mixed – White & Black African	1 (2%)	1 (4%)
Black / African / Caribbean / Black British - Caribbean	5 (10%)	2 (8%)

Other ethnic group - any other background	1 (2%)	1 (4%)
White- British	36 (74%)	20 (77%)
Asian / Asian British – Chinese	1 (2%)	1 (4%)
BMI status		
Underweight (<18.49kg/m²)	-	0 (0%)
Healthy Weight (18.50-24.99 kg/m²)	-	13 (50%)
Overweight (25.00-29.99 kg/m²)	-	8 (31%)
Obese (>30.00 kg/m²)	-	5 (19%)

185

3.1.1 Methods used to assess changes in body shape and size

187 In the questionnaire, participants were asked how they usually assess for changes in their

188 body shape and size. Across all age groups, the most common methods for assessing changes

189 to body shape and size were how their clothes fit and looking at their reflections in the mirror

190 (Figure 2). Clothing fit was the primary method used to assess changes in body shape by

191 participants aged over 36 years of age. In contrast, for participants in the youngest age group

192 (18-25 years), looking in the mirror was the most common method (76%), followed by clothing
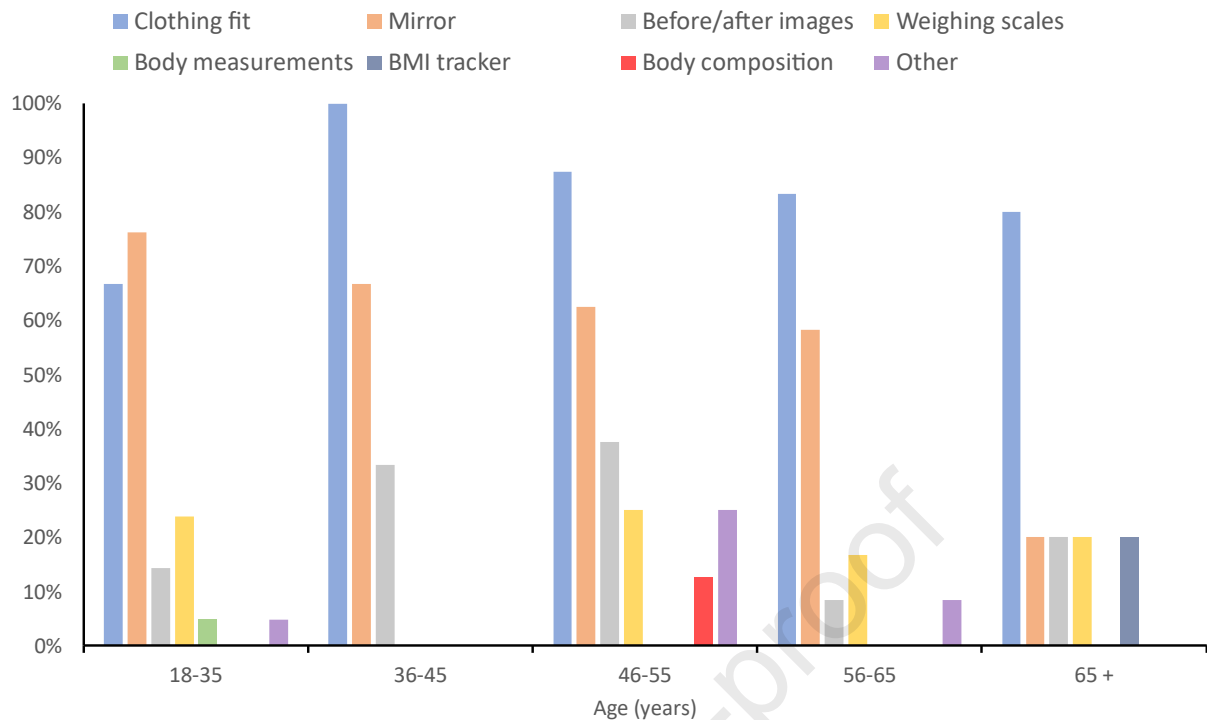
193 fit (60%).

Figure 2. Proportion of respondents within different age categories that use different methods for assessing changes in body shape and size.

Nb: Body measurements= use of an anthropometric tape for girth or length measurement e.g., hip circumference; Before/after images= the use of photographs and images to monitor and measure changes in weight

For both male and female respondents, the most common methods for assessing changes in body shape were clothing fit and looking in the mirror (Figure 3). Female respondents also mentioned using subjective measures such as mobility, walking speed and energy levels, as well as looking at before and after images. One female respondent, who disclosed additional health issues, also mentioned using a BMI tracker. Whereas none of the females reported using traditional body measures, such as waist girth. For the male respondents, the two most common methods for assessing changes in body shape were looking in the mirror and clothing fit. In contrast to the female respondents, 11% of male respondents reported using body measures to assess changes in their body shape.

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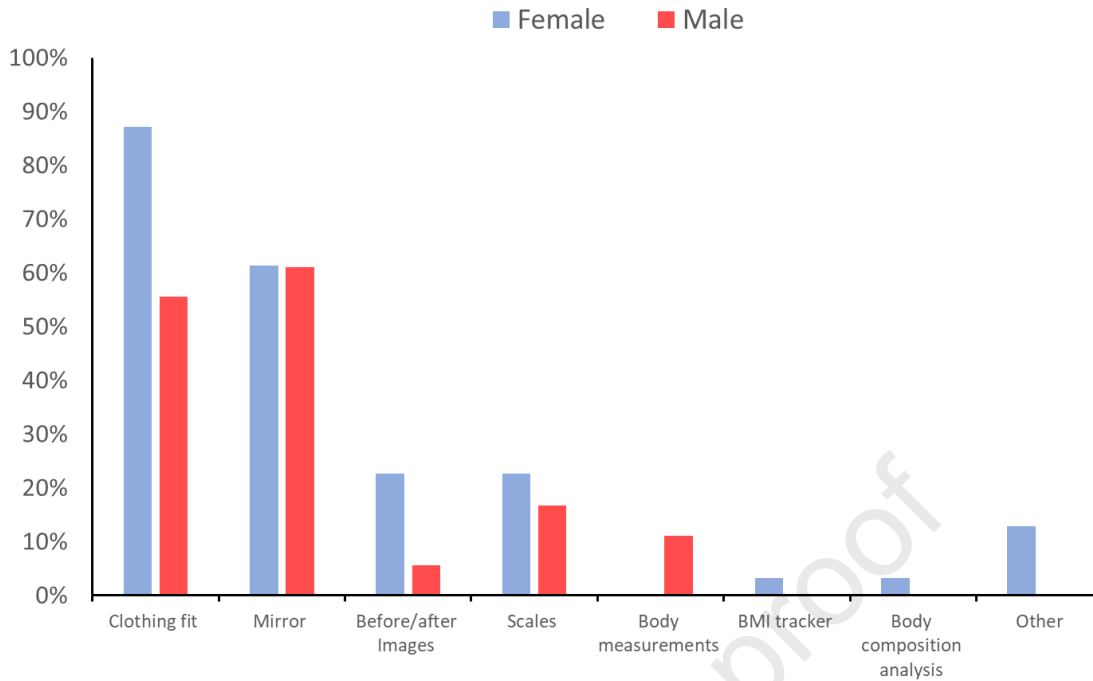
Figure 3. Proportions of males and females that use different methods for assessing changes in body shape.

3.1.2 Tools used by you or someone else to measure your body in the past

The online questionnaire also asked participants what tools have they or someone else used to measure their body in the past. This could have included measures taken by medical practitioners, gym instructors or other health professionals. For both male and female respondents, the tool they reported as having been used most often by themselves or others to measure their body were weighing scales (Figure 4). In addition, around 50% of males and females both report that they have been measured using a tape measure by themselves or others previously. This is contrary to the methods they report using to assess changes in their body shape regularly themselves. There were no meaningful differences in tools used between different age or ethnic groups.

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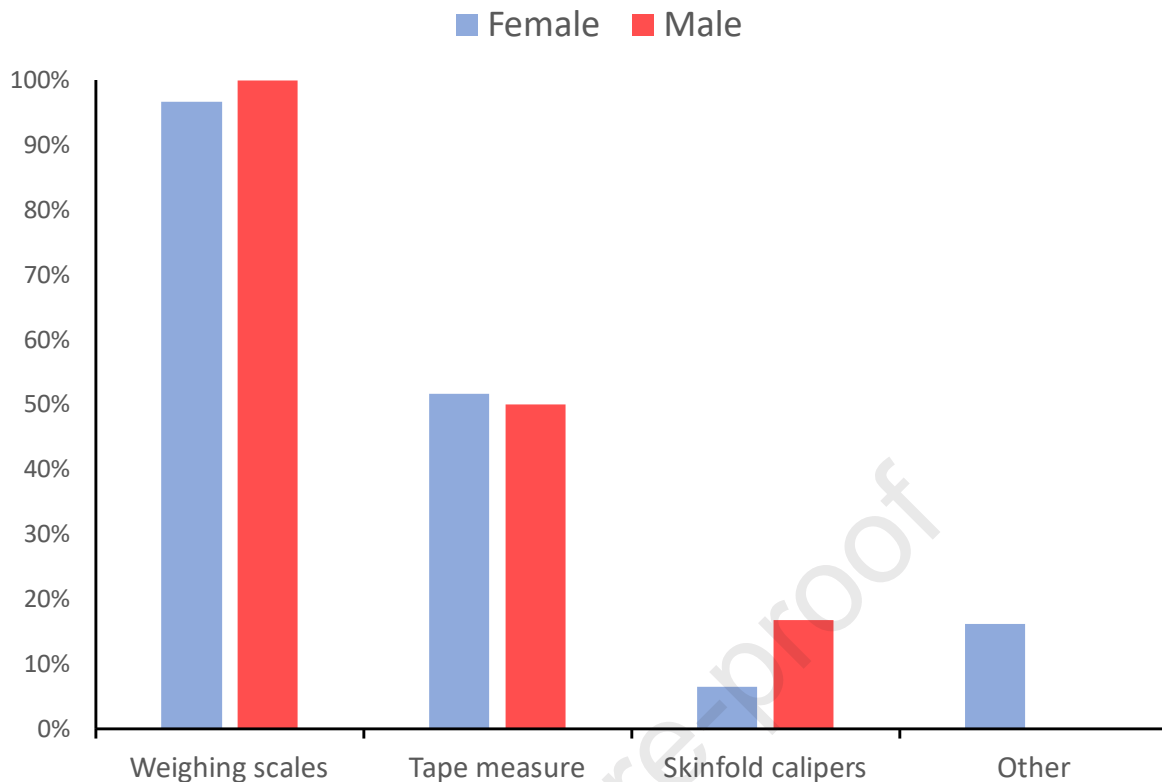
Figure 4. Proportions of males and females that have used/been measured using different body measurement tools.

225

3.2 Part 2: Semi-Structured Interviews and 3D Surface Imaging

227 In the second stage of this study, participants were selected through purposive sampling.

228 Individuals who completed the online questionnaire, had consented to being contacted about

229 further research, and who were not at risk from the BDD screen were invited to complete

230 semi-structured interviews. In total, interviews were conducted with 26 individuals, with

231 equal numbers of males and females as well as a good spread of ages, BMI values and

232 ethnicities throughout the sample.

16

233   Three overarching themes were identified following thematic synthesis; (1) Technology; (2)

234   Participant experience and (3) Perceived benefits and uses. Each theme was then divided into

235   sub-categories and responses were analysed before and after experiencing the various

236   measures of body morphology, as described in the methods. A summary of themes and sub-

237   themes can be found in Table 3.

238

239   *Table 3. Themes and sub-themes from qualitative interviews with example quotes (BMI= Body Mass Index; IMD= Index of Multiple Determinants of Deprivation).*

Themes	Sub-themes	*Example quotes*
1. Technology	1.1 Translation of technology outputs into user friendly messaging	*"And if you're just measuring (data) for measuring's sake, no point. If, if the technology is designed to capture more information, so it can be used in terms of health care and monitoring your health going forward. It's got to be positive." (P19 Male, Chinese, 23 yrs, BMI: 26.2, IMD: 3)* *"I find that quite difficult to interpret the figures. The image is very clear. But all those figures. I'm like, Ooh, I don't know." (P16 Female, White British, 64 yrs, BMI: 34.4, IMD: 9)* *"You can see your own body shape... very, very obvious way. Tells the... like the parts in your body that usually you can't measure by traditional method." (P19 Male, Chinese, 23 yrs, BMI: 26.2, IMD: 3)* *"Because it (the 3D surface imaging device) gives you so much information. The fact it gives you your arms, your legs, your neck...(...) whereas that (weighing scales, tape measure and stadiometer) gives me just a little bit of... a little bit of information, that gives me a lot of information." (P22 Female, White British, 52 yrs, BMI: 41.9, IMD: 6)* *"You get, you know, the blue and red images is a good way, a more accurate way of doing it rather than just standing on a scale. It gives you....you get an idea of places where you need to lose weight. And you also know when you're*

		losing too much weight.....but it's a good way of doing it rather than standing on a scale." (P15 Female, White British, 60 yrs, BMI: 31.9, IMD: 5) *"I think it's just good for people to see visually certain areas of the body and see what they look like and maybe track progress over time." (P1 Male, White British, 28 yrs, BMI: 24.7, IMD: 9)*
	1.2 Application, practicality and scepticism	*"I think anything that's non-invasive is good. No contact, no physical contact. I said before about that, you know - some people don't like to be touched....especially by strangers." P18 Male, White British, 64 yrs, BMI: 36.2, IMD: 1)* *"I was expecting it's just going to be some photos.....I didn't expect it to be so quick. I think that I was in the TARDIS." (P14 Male, White British, 28 yrs, BMI: 24.7, IMD: 9)* *"I think it's important to have both. You need... you need that visual look, to bring it home to you that you are fat. But you also need the numbers to compare against your body mass and to also bring it home that you are overweight for your height. So, you need both really. It works side by side." (P15 Female, White British, 60 yrs, BMI: 31.9, IMD: 5)*
	1.3 Novel technology	*"It's a completely new thing to me. So, I was excited to see the picture." P2 Female, Other, 24 yrs, BMI: 25.3, IMD: 4* *"...it's not intrusive, and, and the data that you get from it is phenomenal." P26 Female, White British, 55 yrs, BMI: 22.1, IMD: 2*

		"It was a bit of a shock to see me there in 3D." P15 Female, White British, 60 yrs, BMI: 31.9, IMD: 5 *"I look forward to seeing it in the hospital. If it ever gets that far!" (P18 Male, White British, 64 yrs, BMI: 36.2, IMD: 1)*
2. Participant Experience	2.1 Questioning the validity of the method	*"I guess waist is probably the most standard measure. Mine seems to vary considerably, depending on things like, what stage of my cycle I'm in and that sort of thing. I tend not to do it that often because... because of that, because of the fluctuations." P9 Female, White British, 35 yrs, BMI: 26.7, IMD: 7* *"I don't believe it (the weighing scales)....partly. Because I look at myself and I see, well it hasn't changed much. I may be wrong. Maybe there are changes going on there that I don't pick up. Maybe I should believe it a bit more, but..." P10 Male, White British, 74 yrs, BMI: 29.2, IMD: 5*
	2.2 Positive Experiences	*"Um, no, it wasn't scary. It was actually comfortable. Yeah." P2 Female, Other, 24 yrs, BMI: 25.3, IMD: 4* *"And I think it's a good indication of kind of where you are (body weight), because I know that my weight should be maintained. So, I kind of know the figure I'm looking for." P6 Female, White British, 24 yrs, BMI: 24.9, IMD: 8* *"They're easy. They're quick. They're very accessible. You've just got to sort of stand on the set of scales, put the tape measure around your waist and look at that, so they're dead easy, they're quick and convenient. Easy to use." P9 Female, White British, 35 yrs, BMI: 26.7, IMD: 7* *"I just notice that a lot of my clothes that I have - particularly suits for work and that - are all too big now because I've lost some weight and...my trousers, I used*

		to always get 32 waist. Now I quite easily fit into a 30. Boring, but good." P24 *Male, White British, 57 yrs, BMI: 22.6, IMD: 5*
	2.3 Negative Experiences	*"And, different brands of clothes measure very, very differently. So you've got to think, I've put a size 10 and it will be equal to a size 12."* P26 *Female, White British, 55 yrs, BMI: 22.1, IMD: 2* *"Because then I think you get into that body dysmorphia thing where you just overanalyse and self (assess too much than what is mentally healthy, I think."* P25 *Male, White British, 26 yrs, BMI: 21.7, IMD: 5* *"I suppose it's the same thing as a scale. You could get to the point where you're trying to pinpoint tiny, micro, little changes in your body and, you know, oh, I want to improve my bust, or I want to get rid of my thighs, or I want to do that, and I suppose that level of getting obsessive with things."* P22 *Female, White British, 52 yrs, BMI: 41.9, IMD: 6* *"It is a bit intrusive (manual measures)...especially when you know you're fat. It's like thinking, oh, you know, this is terrible, really. Because you can...you can feel the tape going around you, and you know it's going to be a big measurement. So, it's intrusive in that way."* P15 *Female, White British, 60 yrs, BMI: 31.9, IMD: 5* *"I'm okay about it, but I can see not everybody would be comfortable with that because... especially when it comes to weight, people would be a bit uncomfortable, especially that you're touching them."* P17 *Female, Black Caribbean, 51 yrs, BMI: 30.1, IMD: 2*

3. Perceived Benefits and Uses	3.1 What does the 3D surface image represent and what additional benefits it brings	*"Because if this equipment is in the gym, I think people they will see their body shape changing over time. Because it shows a direct image of myself. So then I'll see like which parts I need to more focus on." P19 Male, Chinese, 23 yrs, BMI: 26.2, IMD: 93* *"It can show you as opposed rather than just looking in the mirror... how you're like... what your posture is (indistinct) for like postural control….I know that my left shoulder is either higher or lower. (Indistinct) I got hit by a car." P12 Male, White British, 25 yrs, BMI: 22.9, IMD: 8*
	3.2 Interest in knowledge and data generated	*"To have it there shown that these are the places where you are fat. And you've got to do something about it. It's like, almost like having a blood test, isn't it? You know, you've got the results and you're there, and it's staring at you." P15 Female, White British, 60 yrs, BMI: 31.9, IMD: 5* *"I don't like looking at the image though. I REALLY don't like that picture of me. But then on the other hand, that's... that's how I look." P16 Female, White British, 64 yrs, BMI: 34.4, IMD: 9*
	3.3 Motivational and emotional response to using body measurements	*"I was diagnosed with fatty liver. And it scared me a bit......So I just think generally I might... I would benefit from some weight loss. But you know, when I... undress, I'm quite appalled at the way I look really. But, it should shock people into doing something." P15 Female, White British, 60 yrs, BMI: 31.9, IMD: 5* *"I suppose my motivation are, I play football, bit of sports, so I like to be obviously fit and healthy for that. The other reason's purely for like aesthetics, just to obviously look a certain way….like looking in the mirror in the morning*

22

		or an afternoon after you've had a workout…seeing if you've made any progress…I sort of track how much I weigh every now and again....I don't really put much importance into that really. it's more about the visual, rather than the actual reality, I suppose." P1 Male, White British, 28 yrs, BMI: 24.7, IMD: 9
		"Yes, it would (help me)...because I'll be checking my body every time. How much... how much fat have I lost? Or am I putting it on? It (the scan) would be very, very helpful...in about two weeks or after (last GP appointment)." P14 Male, Asian-Bangladeshi, 60 yrs, BMI: 28.6, IMD: 1
		"I really like that....information and then to compare….in another sense, I'd worry I'd get too fixated on it….You know, would I start to lose the will to live by looking at all of them....what would be helpful for me is if I could just say, right, I only want to look at this, this and this....don't give me my calf measurements." P13 Female, White British, 51 yrs, BMI: 20.1, IMD: 10

240

23

3.2.1   Theme 1: Technology

241

242   The subject of technology was a consistent occurrence during the semi-structure interview,

243   which is unsurprising given the fact that none of the participants had experienced the 3D

244   surface imaging device before. Three distinct subcategories were identified during the

245   discussion around technology, which are presented below.

3.2.1.1   *Translation of technology outputs into user friendly messaging*

246

247   Participants were particularly focussed on the data generated from the 3D imaging scanner.

248   They described how the data was both complex to understand initially, but has potential to

249   be useful. Participants described how if the data was used and presented correctly with a

250   meaningful association to health, then it would be considered to be a positive feature.

251   However, some participants expressed concern that the amount of data provided by the 3D

252   surface imaging device might cause them to be overwhelmed, particularly when people are

253   used to simple height, weight and waist girth measurements.

254   Participants alluded to the additional precision and value of having a visual output of your

255   body image, in addition to standard measures of assessing body size and reliance on self-

256   assessment.

257   The ability to obtain site specific images and measures was commented on which was

258   welcomed as useful information, and provided more context to weight loss and weight gain

259   information which could be motivational.

260   The visual output of the 3D image added meaning for participants above "just numbers" and

261   was considered beneficial for tracking changes over time.

262   Participants recognised that they could compare their 3D surface images at multiple

263   timepoints to see how their body shape has changed. This feature has the potential to be

264   beneficial for monitoring both aesthetics and changes in their health.

265   Overall, participants appeared accepting of the surface imaging device and found that it was

266   able to provide useful information which could be generated into user-friendly outputs for

267   both short- and long-term use. However, the vast quantity of data that was provided could

268   be overwhelming, and unnecessary for many and would need to be selected specifically to

269   meet the needs of individuals and to ensure it was presented in a way which was meaningful

270   to the users.

271 *3.2.1.2 Application, practicality and scepticism*

272 Participants described how 3D surface imaging seemed a much less intrusive way of collecting

273 body measures, compared to manual measurements techniques, and felt that it was a more

274 private way of being measured which they commented positively on.

275 Participants described how data capture using the 3D surface imaging device was surprisingly

276 quick, especially for the quantity of data that was collected in comparison to the manual

277 measures, and as a result felt that this could be done by themselves in a GP or leisure centre.

278 However, participants felt that the 3D surface imaging device would need to be used in

279 conjunction with other measures so that body shape could be compared with more familiar

280 outputs such as BMI. They felt that the main drawback of the 3D surface imaging device was

281 the lack of body composition data which was important to their understanding of health.

282 Additionally, the participants were quite insightful about the practicalities of the current kit,

283 which is expensive and takes up a lot of space. They felt that there were some benefits to this

284 such as the possibility of it being easily adapted for wheelchair users but there was an

285 awareness of how the size and cost would not be embedded easily into the current healthcare

286 or primary care environment and would therefore be of limited use.

287 *3.2.1.3 Novel technology*

288 Initially, participants were apprehensive and excited about the use of a new technology, and

289 felt that the 3D surface imaging device was quick, efficient, and accurate.

290 Participants reported that they felt comfortable using the equipment and that this was

291 beneficial, particularly for them to look at trends in their body shape and changes over time.

292   Participants also noted that the surface imaging device was less intrusive than 'hands-on'

293   anthropometry techniques such as waist circumference, as a tool for measuring body shape

294   and size and that it was able to generate large quantities of specific information which

295   accurately described them.

296   Whilst people liked the perceived accuracy of the data that was presented and most felt

297   comfortable with the 3D surface image that they were shown, there was some reports of

298   shock and/or surprise with the output and seeing their bodies from a completely different

299   perspective.

300   It was also apparent that the description of the process given individuals prior to using the 3D

301   surface imaging device was incomplete as participants reported that they expected to be

302   scanned for a longer duration (up to half an hour), that they expected a 'photobooth'

303   countdown and flashing lights or postural adjustments.

304   Some participants felt that the 3D surface imaging device should be rolled out immediately,

305   *IMD,* with additional scaled up trials and deployment for public and professional use.

3.2.2   Theme 2: Participant experience

Theme two explored the participant experience in relation to previous use of methods to determine body weight and shape. Sub-themes that emerged from this discussion were:

3.2.2.1   Questioning of validity and applicability

Several participants were sceptical about the use of traditional methods of assessing body morphology and how applicable the results were to them personally. One main factor was the high degree of fluctuation between monitoring sessions and how this reduced the impact of the result on the individual. These fluctuations caused some participants to use traditional measures less frequently, or with less confidence as a result.

Participants felt that traditional measures of body morphology such as weight and waist circumference over- or under-measured changes in their bodies leading to a sense of disbelief or mistrust in the measurements.

Mistrust of the accuracy of data produced by traditional body measures appeared to be a common theme throughout the qualitative sessions.

3.2.2.2 Positives of body morphology measures

321 There were several consistent positive themes relating to general body morphology

322 measures. The most common being that participants felt that using measures of body

323 morphology permitted the ability to notice change (particularly in body weight) and to assess

324 if they were "on track".

325 A number of participants employed the use of body morphology measures due to the speed

326 and ease at which the measures could be taken, allowing the simple and rapid assessment of

327 current weight status.

328 A third common topic was in relation to using existing clothing as a marker of body size.

329 Additionally, the use of clothing, and how well the garment fit, was described as a measure

330 of success or a motivational driver to facilitate a change in their behaviour.

331 Where participants were used to monitoring their body size and shape using both subjective

332 and objective measures, they reported that these helped to assess whether they were 'on

333 track' and provided a way of motivating themselves to take part in weight loss or gain

334 strategies to maintain their weight.

3.2.2.3 Negatives of body morphology measures.

336 Using clothing to assess body size was a technique utilised by many participants. Though some

337 participants had positive experiences of this method, other discussed their own negative

338 encounters. Inconsistencies in garment sizing between different shops and brands results in

339 lack of confidence in using clothing as a measure of body shape.

340   Some participants discussed their concerns related to varying measures of body morphology,

341   with relation to the wider impact on an individual's wellbeing. A number of participants

342   expressed concerns that the consistent use of body morphology measures could lead to

343   individuals becoming obsessed with their own size and over-analysing the information

344   generated, which could negatively impact the perception of oneself.

345   Some of these negative concerns were particularly related to the results obtained and use of

346   the 3D surface imaging device.

347   After experiencing each of the manual measures of body size and shape, a number of

348   concerns were expressed about the discomfort felt personally, or what others might

349   experience. This was particularly evident for measurements of waist circumference using an

350   anthropometric tape which were described as intrusive.

351   Other participants reported that being touched physically also had the potential to make

352   them or others feel uncomfortable.

353   It was evident from the participants' discussions that both the experience of having the body

354   morphology measures taken, and the manner in which results were presented or perceived

355   were causes of potential discomfort, even in a study population who had volunteered to have

356   their body measurements taken.

357 3.2.3 Theme 3: Perceived benefits and uses

358 *3.2.3.1 What does the 3D surface image represent and what additional benefits it brings?*

359 Several participants saw the benefits of being able to gain a more in-depth view of their

360 physique and being able to view it from different perspectives, as opposed to just seeing a

361 weight value. Some participants seemed to have a perception that because the 3D surface

362 imaging device enabled them to see where their body mass was distributed and they could

363 see where they had greater amounts of mass, that they then might be able to target specific

364 areas on their body to lose weight through diet or exercise.

365 As an adjunct to weight monitoring, participants identified other potential benefits of using

366 the 3D surface imaging device, such as changes in posture.

367 This type of information could potentially have uses within rehabilitation or physiotherapy

368 applications for those living with obesity, where muscular imbalances have been identified

369 but are not perceptible to the patient. These body images could be shown to the patient to

370 help them visualise these issues and then monitor improvements over time following

371 remedial physical therapy.

372   *3.2.3.2   Interest in knowledge and data generated*

373   Several participants seemed to have a genuine interest in the data generated by the 3D

374   surface imaging device and how it could be used, this appeared to correlate primarily with

375   individuals who described an interest in quantitative data. These individuals commented on

376   how they liked the objective nature of the data produced by the 3D surface imaging device,

377   likening it to having a blood test. For these individuals, this data provided an objective

378   representation of what their body looks like, which they couldn't avoid.

379   Though some participants commented that they didn't like seeing the images, they

380   recognised that it at least gave them an objective measure of their body shape, which they

381   could then use as a starting point for them to then make changes.

382   However, it is hard to determine from this study, whether people would be able to use the

383   data objectively to make appropriate lifestyle changes in order for them to achieve their

384   weight goals, or whether the emotional response to seeing the images would override the

385   ability to interpret and process the available data.

3.2.3.3   *Motivational and emotional response to using body measurements*

386

387   Several participants discussed health concerns being a primary motivator for measuring their

388   body, either because of health issues that they have previously had themselves, or health

389   issues that other members of their family have suffered from, which they could potentially

390   also be at risk of.

391   Other primary motivations for participants collecting body measurements included staying

392   healthy to enable them taking part in physical activity and sport, as well as for purely aesthetic

393   reasons.

394   Participants felt that if they could track visual changes in their appearance following periods

395   of exercise, either by seeing how their body shape itself had changed, or by simply whether

396   their clothes fit them well, then they are making good progress rather than whether their

397   weight has changed.

398   There were quite disparate emotional responses to taking body measurements, ranging from

399   a quite pragmatic understanding that they have a purpose within health monitoring, to the

400   potential damaging effects of fixating on body image. Some participants questioned whether

401   having access to improved measures of body shape or the ability to see oneself in a detailed

402   3D surface image might contribute to a perceived need to conform to accepted societal norms

403   of body shape, as well as the risk of body image-related disorders, such as body dysmorphia.

404   Whilst it is positive that people felt that the 3D surface imaging device would be motivational

405   if used appropriately, it would also be important to understand those at risk of becoming, or

406 those being obsessive, with taking body measurements and have a system in place which

407 prevents and addresses this behaviour.

4 Discussion

409 As far as we are aware, this is the first study which provides insight into why individuals use

410 body morphology and body measurement techniques, which measurements are preferred

411 and perspectives of novel 3D surface imaging techniques.

412 Previous research has suggested that having alternative indices of success (besides weight),

413 which increase self-efficacy and perceived autonomy around weight management, could help

414 avoid the failings of short-term weight loss goals by embedding longer term indicators of

415 success which are acceptable to participants [56]. In the current study, participants measured

416 changes in their body shape and size by how their clothes fit, looking in the mirror and using

417 weighing scales, although there were some gender differences with females also comparing

418 before and after photographs of themselves, and using more subjective measures of health

419 such as perceived fitness levels. However, previous research suggests that measures such as

420 clothing fit, and size can be variable, unreliable and may lead to altered body dissatisfaction

421 and confidence [57].

422 Recent evidence suggests that self-monitoring of body weight is associated with successful

423 weight-loss outcomes [58] [59] and is a popular practice within many weight-management

424 interventions [60]. Given the potential benefits related to improving the effectiveness of

425 weight-loss interventions, little evidence exists alluding to the habitual frequency of self-

426 weighing, or other self-applied techniques of assessing body morphology.

427   In addition to the lack of evidence of regular self-monitoring of body size, there is little

428   evidence of why people might self-monitor in the first instance. In the current study, though

429   almost all of the participants reported that they have had their body weight monitored by

430   someone else in the past, only ~15-20% of participants regularly use weighing scales

431   themselves, with clothing fit and mirror image being the most used techniques. Chambers

432   and Swanson (2012) stated that self-weighing allows people to take appropriate action based

433   on fluctuations in their body weight and is thus an effective self-monitoring technique [61].

434   However, despite evidence of minimal harmful psychological effects of regular self-weighing

435   [62], a potential negative impact identified in the analysis relating to all measures of body size

436   was on body perception. Participants in the current study opted for more visual and

437   perceptual measures of their body, with some attributing this to aesthetic reasons, although

438   previous research suggests that mirror-based observations of size are of variable accuracy

439   [63]. However, participants felt that perceptual changes derived from clothing fit and

440   reflection in the mirror, were a better indicator of their progress than weight on a scale. Other

441   primary motivations for participants collecting body measurements included staying healthy

442   to enable them taking part in physical activity and sport. However, several participants

443   discussed health concerns being a primary motivator for measuring their body, either because

444   of health issues that they have previously had themselves, or health issues that other

445   members of their family have suffered from, which they could potentially also be at risk of.

446   This is supported by prior research which demonstrates a beneficial effect of self-monitoring

447   of health metrics in weight management [64]. Therefore, people may benefit from being able

448   to self-monitor potential indicators of health risks (i.e., waist circumference, fat %) via the use

449   of novel technologies such as 3D surface imaging, rather than waiting for their healthcare

450   provider to identify issues. This ability to self-measure body morphology to a higher degree

451   of accuracy and granularity could also perhaps provide individuals with a sense of

452   empowerment in being able to take charge of their own health. This data provides evidence

453   that the motivations behind self-monitoring of body size range from increasing or maintaining

454   physical capability, improving or maintaining health and attaining favourable aesthetic

455   results.

456   BMI and waist circumference measures are widely used in the UK and recommended by NICE

457   weight management guidelines [65]. Participants were familiar with standard body

458   morphology measurements such as height, weight, waist circumference and BMI and still felt

459   that these measures were valuable to them and their understanding of health. However,

460   when participants were asked in the online questionnaire what methods they used to assess

461   changes in their body shape and size, only a small proportion of individuals reported using

462   these traditional body measures regularly themselves, preferring instead to use more visual

463   or subjective measures. Whilst traditional measures, such as BMI, are widespread and familiar

464   to the UK population, they have been heavily criticised as they do not reflect the adiposity or

465   lean tissue composition of an individual and therefore poorly correlate to health [66]. Despite

466   over 50% of respondents in part 1 of the study stating that body measurements (girth or

467   circumference measured by an anthropometric tape) had been employed by either

468   themselves or by others in the past, only 11% of male respondents and no female respondents

469   reported using this method regularly. When this topic was explored in part 2 of the study, it

470   became apparent that some participants found the use of the anthropometric tape to be

471   uncomfortable and intrusive. The use of waist circumference (WC) as a measure of body size

472   has been previously examined from both a practitioner and patient perspective. Interestingly,

473 though few barriers were raised from the patients with regards to the use of WC, the

474 perspective of the practitioners was that some patients might feel embarrassed about the

475 measure, and that it was a time-consuming process [67]. There appears to be a possibility

476 that a combination of the practitioners' reluctance to conduct WC measurements, coupled

477 with the negative perceptions of WC measurements expressed in the current study, might be

478 a reason why so few participants reported using body circumference to track changes in body

479 shape and size. However, despite their familiarity with traditional methods, participants felt

480 that the 3D images provided more accurate, objective information which was more site-

481 specific, and that this data was a useful adjunct to more traditional measures.

482

483

484 The main reported benefit of the 3D surface imaging device was that it was perceived to

485 provide a large volume of accurate information, quickly and in a non-intrusive manner. Given

486 that several participants expressed concerns over the validity and applicability of traditional

487 methods of measuring body shape and size, this element of accuracy is of particular

488 significance. However, participants perceived that the 3D surface imaging data was more

489 accurate than traditional methods, despite having no evidence to validate this. Some research

490 has shown that whilst 3D surface imaging devices have great replicability of results, and

491 remove the human error associated with traditional body measurements, they may

492 overestimate waist and thigh circumference, particularly in those with smaller thigh

493 circumferences [68]. Whilst the quantity of information had value for some, it was considered

494 overwhelming for others. This then suggests that further work would be necessary to identify

495   the key information from the imaging device and how to present this in the most useful

496   format so that individuals can understand and use data which is meaningful to them in an

497   actionable way. This process of meaning-making from data has been categorised into 3 areas-

498   supporting digital data practices, interpretation and contextualisation, and inclusion and

499   interaction [69]. This would also involve additional training of healthcare professionals or

500   leisure centre staff where 3D surface imaging services are available.

501   The speed of 3D surface imaging, a common positive experience reported by participants, as

502   opposed to the manual measures is beneficial and may help to increase engagement with

503   attendance at appointments, or frequency at which HCPs are able to take measurements. A

504   criticism of manual measures is that they are time-consuming, especially when multiple

505   measurements are required [70] so the 3D surface imaging device offers a distinct advantage

506   in terms of the amount of time to collect measures.

507   Perhaps most importantly, the non-intrusive manner in which the 3D surface imaging device

508   collects data could be of most benefit, as several participants expressed negative experiences

509   when waist circumference was measured, as observed in previous literature [11]. By

510   providing a 3D surface image as an alternative measure of body morphology, especially for

511   those patients who are deterred from attending clinical appointments due to the current

512   invasive methods, 3D surface imaging could improve uptake of appointments and provide a

513   more inclusive, low-stigma environment [10] [11]. Also, there was a sense that the ability to

514   measure body morphology to a higher degree of granularity could also perhaps provide

515   individuals with a sense of empowerment in being able to take charge of their own health. In

516   contrast, some participants expressed concerns about potential damaging effects of fixating

517   on body image and targeting weight loss from specific locations, and that having the ability

518   to see oneself in a detailed 3D surface image might contribute to a perceived need to conform

519   to accepted societal norms of body shape, which could put people at risk of body image-

520   related disorders, such as body dysmorphia [49]. However, there is insufficient evidence to

521   support targeting weight loss from specific locations on the body [71] [72], so this might give

522   users unattainable goals, if they are focused on changing the shape of a specific part of their

523   body, which could cause them to become demotivated when that aspect of their shape

524   doesn't change as they hope.

525   Previously, healthcare professionals have been criticised for inadequate communication skills,

526   lack of training and use of stigmatising language when performing body measurement 3D

527   surface imaging is an accepted methodology and may reduce anxiety in assessments [73]

528   which may also contribute to the negative perceptions of body morphology measures. The

529   use of people-first language and effective communication of information is vital irrespective

530   of the method used to capture body measurements, Therefore, training will need to be

531   delivered with practitioners prior to the adoption of any new technologies, including

532   disseminating the outputs of the 3D surface imaging device with individuals in a people-first,

533   inclusive language which is actionable for individuals [74].

4.1 Strengths and Limitations

534

535 As far as we are aware, this is the first study which assesses the perspectives of a diverse

536 group of individuals on the experience and use of 3D surface imaging technology as an

537 alternative or adjunct to traditional body morphology measurements. The study recruited a

538 diverse range of males and females from different ethnic backgrounds, areas of deprivation

539 and age groups, representative of the local population. The study assessed acceptability of

540 the technology and participants suggested additional potential uses of the 3D surface imaging

541 device to consider in future work.

542 At present, the large range of available hardware, software, calibration techniques,

543 anthropometric definitions, and data collection procedures used by different 3D imaging

544 systems, makes the comparison of body composition estimates from these devices difficult,

545 thereby limiting its suitability for use in research and practice. Whilst 3D imaging can provide

546 some data regarding fat distribution, it is not a direct measure of body composition, nor is it

547 specifically validated as a predictor of cardiometabolic outcomes. A further critical review of

548 3D surfacing imaging as a method of estimating body composition is presented by Heymsfield

549 et al. [34], with further research suggested in this article required to support the use of 3D

550 imaging in clinical practice.

551 However, this is still a relatively small sample size due to the exploratory nature of this initial

552 study and further research is required to fully understand the psychological implications of

553 using this type of technology within healthcare or commercial settings in a larger population

554 group. 3D imaging is not a recommendation in obesity management recommendations for

555 clinicians or practitioners.

4.2 Recommendations for practice

556

557 There is a need to recognise that traditional body measurements and body morphology can

558 feel intrusive, awkward and stigmatising for some individuals and that in some cases, this can

559 prevent or delay access to healthcare. Body measurements should always be done in

560 discussion with the individual, in an appropriate setting and only when deemed clinically

561 relevant or necessary. For individuals who feel uncomfortable with traditional measures and

562 methods, alternative solutions should be considered. 3D surface imaging may be a suitable

563 alternative method for collecting body measures for some individuals, with detailed measures

564 able to be collected quickly and without requiring physical contact from a healthcare

565 professional or other practitioner. However, further training on non-stigmatising, people-first

566 language and how to share 3D surface imaging information in a meaningful way should be

567 prioritised.

4.3 Future research

568

569 Future research should investigate the use of low-cost tools to acquire shape anthropometrics

570 from the surface of the body, enabling all practitioners to assess human morphology without

571 relying on expensive 3D surface imaging devices. Most 3D surface imaging devices are large

572 pieces of equipment which are generally static, and though some devices have translated

573 from fixed laboratory instruments into commercially available portable devices, they

574 currently cost significantly more than traditional weighing scales and body measurement

575 tools frequently used in practice. However, more portable body morphology measurement

576 tools are being developed. These low-cost tools could either be physical objects, allowing

577 practitioners to manually measure body shape features such as curvature and simple ratios,

578 or 3D imaging apps which can be embedded into lightweight devices such as smartphones or

579   tablets and are able to replicate the outputs of existing 3D surface imaging systems and

580   capture shape anthropometrics to a required level of accuracy.

581   In addition, if 3D imaging technologies are to be of benefit to population health, there needs

582   to be assessment to understand whether these technologies have a specific, long-term

583   benefit to weight and obesity management in comparison to traditional anthropometry

584   techniques.

585   In conjunction with this, people with lived experience of being measured in a 3D surface

586   imaging device should be involved in co-developing a description of the procedure to provide

587   to patients prior to their appointment to reduce any anxiety and set expectations. Whilst this

588   paper initiates discussion regarding individuals' perceptions of body contour and shape, and

589   how they might use this data, this would be worthy of further research.

590   Additional research is required to assess how the technology can be used at scale, and the

591   training and resource needs required for successful implementation in public health and

592   wellbeing environments. The impact of the availability of this technology to weight

593   management also warrants further investigation.

5   Conclusion

595   The study aimed to understand acceptability of traditional and 3D surface imaging-based

596   anthropometric measures.

597   • Traditional methods of assessing body shape and size, such as weighing scales and

598   circumference measures, were found to be seldom used in comparison to more

599   subjective, aesthetic measures, such as reflection in the mirror or clothing fit.

600   •   The novel 3D surface imaging device was widely accepted by participants and was

601   perceived to have some benefits over traditional anthropometric measures such as

602   being less intrusive, quick, accurate and able to produce detailed additional

603   information to assess body shape changes over time.

604   •   However, data produced by the 3D surface imaging device was recognised to be

605   complex, overwhelming and would require effective training and communication

606   strategies for healthcare professionals and service users for the results to provide

607   useful health metrics as an adjunct to traditional anthropometric techniques.

608

609 **Disclosures:**

610 Declarations of interest: none

615 **Author contribution:** (CRediT authorship contribution statement)

616 The concept of the submission was by LN, MT, SM and SC. Methodology development was

617 done by LN, MT, SM and SC. Data curation was done by MT, SM and AC. Formal analysis was

618 done by LN, MT, SM, SC and AC. Funding acquisition was done by LN, MT, SM and SC. The

619 original draft was prepared by LN, MT and SM. The final draft of the manuscript was reviewed,

620 edited, and approved by LN, MT, SM, SC and AC.

621 **Ethical review:**

622 All procedures were approved by the University Research Ethics Committee Sheffield Hallam

623 University, reference number ER41719941.

627 **Declaration of Artificial Intelligence (AI) and AI-assisted technologies.**

628 During the preparation of this work the authors did not use AI.

629 **Supplementary data**

630 Questionnaire- the online questionnaire which collated the demographic data and screened

631 for BDD.

632   Semi-structured interview guide- the interview guide which was used during the qualitative

633   interviews.

634

Reference List

1. World Health Organization. n.d. Obesity. https://www.who.int/health-topics/obesity/#tab=tab_1. 2023.

2. Prospective Studies Collaboration, G. Whitlock, S. Lewington *et al*. 2009. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. Lancet. 373: 1083-1096.

3. World Health Organization. 2000. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health. Organ. Tech. Rep. Ser. 894: i-253.

4. World Health Organization. 2008. Waist Circumference and Waist–Hip Ratio. Report of a WHO Expert Consultation. Geneva, 8-11 December 2008.

5. Wells J., P. Treleaven & T. Cole. 2007. BMI compared with 3-dimensional body shape: the UK National Sizing Survey. Am. J. Clin. Nutr. 85: 419-425.

6. Duren D. L., R. J. Sherwood, S. A. Czerwinski *et al*. 2008. Body composition methods: comparisons and interpretation. J. Diabetes Sci. Technol. 2: 1139-1146.

7. Piché M., P. Poirier, I. Lemieux *et al*. 2018. Overview of Epidemiology and Contribution of Obesity and Body Fat Distribution to Cardiovascular Disease: An Update. Prog. Cardiovasc. Dis. 61: 103-113.

8. Thelwell M., A. Bullas, A. Kühnapfel *et al*. 2022. Modelling of human torso shape variation inferred by geometric morphometrics. PLOS ONE. 17: e0265255.

9. Rothman K. J. 2008. BMI-related errors in the measurement of obesity. Int. J. Obes. 32: S56-S59.

10. Benn Y., T. L. Webb, B. P. I. Chang *et al*. 2016. What is the psychological impact of self-weighing? A meta-analysis. Health. Psychol. Rev. 10: 187-203.

11. Geier A. B. & P. Rozin. 2008. Weighing discomfort in college age American females: Incidence and causes. Appetite. 51: 173-177.

12. Winter V. R., K. Trout, E. Harrop *et al*. 2023. Women's refusal to be weighed during healthcare visits: Links to body image. Body Image. 46: 41-47.

13. Wells J., A. Ruto & P. Treleaven. 2008. Whole-body three-dimensional photonic scanning: a new technique for obesity research and clinical practice. Int. J. Obes. (Lond). 32: 232-238.

14. Douros I. 2004. Calculating the Curvature Shape Characteristics of the Human Body from 3D Scanner Data.

666   15. Barnes R. 2010. The Body Volume Index (BVI): Using 3D Scanners to Measure and Predict
667   Obesity . Proc. of 1st Int. Conf. on 3D Body Scanning Technologies.

668   16. Thelwell M., C. Chiu, A. Bullas *et al*. 2020. How shape-based anthropometry can
669   complement traditional anthropometric techniques: a cross-sectional study. Sci. Rep. 10:
670   12125-4.

671   17. Hamad M., S. Thomassey & P. Bruniaux. 2017. A new sizing system based on 3D shape
672   descriptor for morphology clustering. Comput. Ind. Eng. 113: 683-692.

673   18. Löffler-Wirth H., E. Willscher, P. Ahnert *et al*. 2016. Novel Anthropometry Based on 3D-
674   Bodyscans Applied to a Large Population Based Cohort. PLoS One. 11: e0159887.

675   19. Pleuss J. D., K. Talty, S. Morse *et al*. 2019. A machine learning approach relating 3D body
676   scans to body composition in humans. Eur. J. Clin. Nutr. 73: 200-208.

677   20. Wells J. C. K. 2019. Three-dimensional optical scanning for clinical body shape assessment
678   comes of age. Am. J. Clin. Nutr. 110: 1272-1274.

679   21. Daanen H. & F. B. Ter Haar. 2013. 3D whole body scanners revisited. Displays. 34: 270-
680   275.

681   22. Bullas A. M., R. Greenwood, M. Thelwell *et al*. 2022. A Review of Commercially Available
682   3D Surface Imaging Systems for Body Composition Estimation. Applied Sciences. 12.

683   23. H. A. M. Daanen, M. A. Brunsman & K. M. Robinette. 1997. Reducing movement artifacts
684   in whole body scanning. *In* Proceedings. International Conference on Recent Advances in 3-D
685   Digital Imaging and Modeling (Cat. no.97TB100134). : 262-265.

686   24. Robinette K. M. & H. A. M. Daanen. 2006. Precision of the CAESAR scan-extracted
687   measurements. Appl. Ergon. 37: 259-265.

688   25. P. Treleaven & J. Wells. 2007. 3D Body Scanning and Healthcare Applications. Computer.
689   40: 28-34.

690   26. Daanen H., M. A. Brunsman & K. M. Robinette. Reducing movement artifacts in whole
691   body scanning. Proceedings International Conference on Recent Advances in 3-D Digital
692   Imaging and Modeling. : 262–5.

693   27. Tzou C. J., N. M. Artner, I. Pona *et al*. 2014. Comparison of three-dimensional surface-
694   imaging systems. Journal of Plastic, Reconstructive & Aesthetic Surgery. 67: 489-497.

695   28. 3dMD. 2020. Static 3dMD systems. 2023.

696   29. Sarbolandi H., D. Lefloch & A. Kolb. 2015. Kinect range sensing: Structured-light versus
697   Time-of-Flight Kinect. Comput. Vision Image Understanding. 139: 1-20.

698   30. Hollander M. H. J., J. Kraeima, A. M. L. Meesters *et al*. 2021. Reproducibility of 3D scanning
699   in the periorbital region. Scientific Reports. 11: 3671.

700   31. P. J. Besl & N. D. McKay. 1992. A method for registration of 3-D shapes. IEEE Transactions
701   on Pattern Analysis and Machine Intelligence. 14: 239-256.

702   32. Allied Market Research: 3D Scanning Market Outlook–2030. 2022. 2022.

703   33. Ng B. K., B. J. Hinton, B. Fan *et al*. 2016. Clinical anthropometrics and body composition
704   from 3D whole-body surface scans. Eur. J. Clin. Nutr. 70: 1265-1270.

705   34. Heymsfield S. B., B. Bourgeois, B. K. Ng *et al*. 2018. Digital anthropometry: a critical review.
706   Eur. J. Clin. Nutr. 72: 680-687.

707   35. Milanese C., A. Giachetti, V. Cavedon *et al*. 2015. Digital three-dimensional anthropometry
708   detection of exercise-induced fat mass reduction in obese women. Sport Sciences for Health.
709   11: 67-71.

710   36. Harbin M. M., A. Kasak, J. D. Ostrem *et al*. 2018. Validation of a three-dimensional body
711   scanner for body composition measures. Eur. J. Clin. Nutr. 72: 1191-1194.

712   37. Wong M. C., B. K. Ng, S. F. Kennedy *et al*. 2019. Children and Adolescents' Anthropometrics
713   Body Composition from 3-D Optical Surface Scans. Obesity (Silver Spring, Md.). 27: 1738-
714   1749.

715   38. Ng B. K., M. J. Sommer, M. C. Wong *et al*. 2019. Detailed 3-dimensional body shape
716   features predict body composition, blood metabolites, and functional strength: the Shape Up!
717   studies. Am. J. Clin. Nutr. 110: 1316-1326.

718   39. Tinsley G. M., M. L. Moore, J. R. Dellinger *et al*. 2020. Digital anthropometry via three-
719   dimensional optical scanning: evaluation of four commercially available systems. Eur. J. Clin.
720   Nutr. 74: 1054-1064.

721   40. Gallagher D., A. Andres, D. A. Fields *et al*. 2020. Body Composition Measurements from
722   Birth through 5 Years: Challenges, Gaps, and Existing & Emerging Technologies-A National
723   Institutes of Health workshop. Obes. Rev. 21: e13033.

724   41. Bennett J. P., Y. E. Liu, B. K. Quon *et al*. 2022. Assessment of clinical measures of total and
725   regional body composition from a commercial 3-dimensional optical body scanner. Clinical
726   Nutrition. 41: 211-218.

727   42. Bartol K., D. Bojanić, T. Petković *et al*. 2021. A review of body measurement using 3D
728   scanning. Ieee Access. 9: 67281-67301.

729 43. Medina-Inojosa J., V. K. Somers, T. Ngwa *et al*. 2016. Reliability of a 3D Body Scanner for
730 Anthropometric Measurements of Central Obesity. Obes. Open Access. 2: 10.16966/2380-
731 5528.122. Epub 2016 Oct 6.

732 44. Mocini E., C. Cammarota, F. Frigerio *et al*. 2023. Digital Anthropometry: A Systematic
733 Review on Precision, Reliability and Accuracy of Most Popular Existing Technologies.
734 Nutrients. 15: 302. doi: 10.3390/nu15020302.

735 45. Choppin S., A. Bullas & M. Thelwell. 2022. Torso Shape Improves the Prediction of Body
736 Fat Magnitude and Distribution. International Journal of Environmental Research and Public
737 Health. 19.

738 46. Adler C., A. Steinbrecher, L. Jaeschke *et al*. 2017. Validity and reliability of total body
739 volume and relative body fat mass from a 3-dimensional photonic body surface scanner. PLoS
740 One. 12: e0180201.

741 47. Tinsley G. M., M. L. Moore, M. L. Benavides *et al*. 2020. 3-Dimensional optical scanning for
742 body composition assessment: A 4-component model comparison of four commercially
743 available scanners. Clinical Nutrition. 39: 3160-3167.

744 48. Deurenberg P. & Y. Schutz. 1995. Body composition: overview of methods and future
745 directions of research. Ann. Nutr. Metab. 39: 325-333.

746 49. Phillips K. A. 2004. Body dysmorphic disorder: recognizing and treating imagined ugliness.
747 World Psychiatry. 3: 12-17.

748 50. Laughter M. R., J. B. Anderson, M. B. C. Maymone *et al*. 2023. Psychology of aesthetics:
749 Beauty, social media, and body dysmorphic disorder. Clin. Dermatol. 41: 28-32.

750 51. Veale D., N. Ellison, T. G. Werner *et al*. 2012. Development of a Cosmetic Procedure
751 Screening Questionnaire (COPS) for Body Dysmorphic Disorder. J. Plast. Reconstr. Aesthet.
752 Surg. 65: 530-532.

753 52. Otter.ai Inc. 2022. Otter.ai.

754 53. Gale N. K., G. Heath, E. Cameron *et al*. 2013. Using the framework method for the analysis
755 of qualitative data in multi-disciplinary health research. BMC Medical Research Methodology.
756 13: 117.

757 54. Smith J. & J. Firth. 2011. Qualitative data analysis: the framework approach. Nurse. Res.
758 18: 52-62.

759 55. Goldsmith L. J. 2021. Using Framework Analysis in Applied Qualitative Research. TQR. 26:
760 2061.

761 56. Teixeira P. J., M. N. Silva, J. Mata *et al*. 2012. Motivation, self-determination, and long-
762 term weight control. International Journal of Behavioral Nutrition and Physical Activity. 9: 22.

763 57. Grogan S., S. Gill, K. Brownbridge *et al*. 2013. Dress fit and body image: A thematic analysis
764 of women's accounts during and after trying on dresses. Body Image. 10: 380-388.

765 58. Burke L. E., J. Wang & M. A. Sevick. 2011. Self-monitoring in weight loss: a systematic
766 review of the literature. J. Am. Diet. Assoc. 111: 92-102.

767 59. Vuorinen A., E. Helander, J. Pietilä *et al*. 2021. Frequency of Self-Weighing and Weight
768 Change: Cohort Study With 10,000 Smart Scale Users. J. Med. Internet Res. 23: e25529.

769 60. Benn Y., T. L. Webb, B. P. I. Chang *et al*. 2016. What is the psychological impact of self-
770 weighing? A meta-analysis. Health Psychology Review. 10: 187-203.

771 61. Chambers J. A. & V. Swanson. 2012. Stories of weight management: factors associated
772 with successful and unsuccessful weight maintenance. Br. J. Health. Psychol. 17: 223-243.

773 62. Katterman S. N., M. L. Butryn, M. M. Hood *et al*. 2016. Daily weight monitoring as a
774 method of weight gain prevention in healthy weight and overweight young adult women. J.
775 Health. Psychol. 21: 2955-2965.

776 63. Farrell C., R. Shafran & C. G. Fairburn. 2003. Body size estimation: Testing a new mirror-
777 based assessment method. Int. J. Eat. Disord. 34: 162-171.

778 64. Fawcett E., M. H. Van Velthoven & E. Meinert. 2020. Long-Term Weight Management
779 Using Wearable Technology in Overweight and Obese Adults: Systematic Review. JMIR
780 Mhealth Uhealth. 8: e13461.

781 65. NICE. 2014. Public health guideline [PH53] Weight management: lifestyle services for
782 overweight or obese adults.
783 https://www.nice.org.uk/guidance/ph53/chapter/glossary#tiers-of-weight-management-
784 services. 2023.

785 66. Nuttall F. Q. 2015. Body Mass Index. Nutrition Today. 50: 117-128.

786 67. Dunkley A. J., M. A. Stone, N. Patel *et al*. 2009. Waist circumference measurement:
787 knowledge, attitudes and barriers in patients and practitioners in a multi-ethnic population.
788 Fam. Pract. 26: 365-371.

789 68. Kennedy S., P. Hwaung, N. Kelly *et al*. 2020. Optical imaging technology for body size and
790 shape analysis: evaluation of a system designed for personal use. Eur. J. Clin. Nutr. 74: 920-
791 929.

792 69. Fiske A., B. Prainsack & A. Buyx. 2019. Data Work: Meaning-Making in the Era of Data-Rich
793 Medicine. J. Med. Internet Res. 21: e11672.

794   70. Rumbo-Rodríguez L., M. Sánchez-SanSegundo, R. Ferrer-Cascales *et al*. 2021. Comparison
795   of Body Scanner and Manual Anthropometric Measurements of Body Shape: A Systematic
796   Review. International Journal of Environmental Research and Public Health. 18.

797   71. Kostek M. A., L. S. Pescatello, R. L. Seip *et al*. 2007. Subcutaneous fat alterations resulting
798   from an upper-body resistance training program. Med. Sci. Sports Exerc. 39: 1177-1185.

799   72. Ramírez-Campillo R., D. C. Andrade, C. Campos-Jara *et al*. 2013. Regional fat changes
800   induced by localized muscle endurance resistance training. J. Strength Cond Res. 27: 2219-
801   2224.

802   73. Sbaih L. C. 1995. What seems to be the matter: communication between hospital and
803   patients-Audit Commission HMSO, London, 1993, ISBN 0-11886-100-X, 75pp,@ $9.00
804   (paperback). Accident & Emergency Nursing. 1: 51.

805   74. Kyle T. K., S. Kahan & J. Nadglowski. 2023. Language Frames and Shapes the Response to
806   Obesity. Gastroenterol. Clin. North Am.

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: