Original Paper

DE GRUYTER OPEN

Biomedical Human Kinetics, 9, 94–98, 2017
DOI: 10.1515/bhk-2017-0014

Comparison of a mobile application to estimate percentage body fat to other non-laboratory based measurements

Matthew P. Shaw[1], Joshua Robinson[2], Daniel J. Peart[3]

[1] Higher Education Sport, Faculty of Business and Science, Hull College, Kingston-upon-Hull, UK; [2] Sport and Biosciences, University Centre, North Lindsey College, Scunthorpe, UK; [3] Department of Sport, Exercise and Rehabilitation, Faculty of Health and Life Sciences, Northumbria University, Newcastle-upon-Tyne, UK

Summary

Study aim: The measurement of body composition is important from a population perspective as it is a variable associated with a person's health, and also from a sporting perspective as it can be used to evaluate training. This study aimed to examine the reliability of a mobile application that estimates body composition by digitising a two-dimensional image.
Materials and methods: Thirty participants (15 men and 15 women) volunteered to have their percentage body fat (%BF) estimated via three different methods (skinfold measurements, SFM; bio-electrical impedance, BIA; LeanScreen^{TM} mobile application, LSA). Intra-method reproducibility was assessed using intra-class correlation coefficients (ICC), coefficient of variance (CV) and typical error of measurement (TEM). The average measurement for each method were also compared.
Results: There were no significant differences between the methods for estimated %BF (p = 0.818) and the reliability of each method as assessed via ICC was good (≥0.974). However the absolute reproducibility, as measured by CV and TEM, was much higher in SFM and BIA (≤1.07 and ≤0.37 respectively) compared with LSA (CV 6.47, TEM 1.6).
Conclusion: LSA may offer an alternative to other field-based measures for practitioners, however individual variance should be considered to develop an understanding of minimal worthwhile change, as it may not be suitable for a one-off measurement.

Key words: Mobile technology – Field testing – Body composition – Reproducibility

Introduction

Obesity is a significant worldwide epidemic [18], increasing in prevalence [4], and resulting in a need to monitor individuals' body composition [1] using accessible tools that allow robust analysis [18]. Body composition measurement is also pertinent from a sporting context, as the values may help practitioners tailor dietary interventions and evaluate training programs [17].

Various methods of measuring body composition are available that have previously demonstrated high validity and reliability, including Hydrostatic Weighing (HW) [3] and Dual Energy X-ray Absorptiometry (DXA/DEXA) [8]. Although there is some disagreement in the literature for what is considered the gold standard assessment of body composition in humans, there is agreement that these methods present difficulties such as expense, time-consumption, access, and portability [11, 14]. Much of this equipment is expensive for front-line practitioners such as primary healthcare workers, nutritionists, personal trainers and strength and conditioning coaches, and is typically restricted to University laboratory / research settings. Skinfold measures (SFM) and bioelectrical impedance analysis (BIA) are inexpensive methods with relatively easy access for practitioners and the general public. Both SFM and BIA have demonstrated validity and reliability in assessing body composition compared to the aforementioned recognised 'gold-standard' methods [20, 26].

With developments in technology comes the potential for more cost-effective solutions in measuring and assessing body composition. A range of smartphone and tablet software applications are now able to validly and reliably measure parameters such as resting heart rate [22] joint range of motion [19, 21] and respiratory function [12, 24], making such technology a potential cost-effective alternative for quantitative data collection.. However, it should also be considered that there is still potential for error in smartphone and tablet technology. For example Peart

Author's address Matthew P. Shaw, Higher Education Sport, Faculty of Business and Science, Hull College, Kingston-upon-Hull, UK
matthew.shaw@hull-college.ac.uk

et al. [22] demonstrated validity and reliability of recording resting heart rate using contactless photoplethysmography via a tablet camera, but could not demonstrate the same reliability recording higher heart rates post-exercise in a follow up study [23]. It was recommended practitioners exercise some caution when using mobile software applications to monitor physiological variables, and not to assume that they work in all contexts.

LeanScreen™ (Postureco, Trinity, Florida, USA) is a smartphone and tablet software application that provides an assessment of body composition using anthropometric measurements digitised from two-dimensional images. Using two-dimensional images to provide accurate anthropometric data is not a new development [7]. There are also more recent applications of digitizing two-dimensional images to provide anthropometric data for specialized purposes such as providing hand measurements for the production of work gloves [6]. However, the validity and reliability of using two-dimensional images beyond surface measurements (i.e. inferences on human tissue composition) is yet to be investigated. The aim of the present study was to compare a specifically designed mobile application to existing field based methods for estimating percentage body fat (%BF).

Materials and methods

Participants

Fifteen male (age = 28.5 ± 10.8 years, stature = 178.9 ± 8.6 cm, mass = 84.5 ± 14.8 kg, body mass index 26.4 ± 4.3 kg/m^2) and fifteen female (age = 30.4 ± 7.2 years, stature = 164.7 ± 7.5 cm, mass = 66.7 ± 11.3 kg, body mass index 24.7 ± 4.9 kg/m^2) adults participated in the investigation. Participants were recruited from local work places to represent a cross sectional sample of the general public. All procedures were approved by an institutional ethics committee, and all participants were volunteers who provided written informed consent in accordance with the Declaration of Helsinki. Each participant had six measurements taken during one visit (twice with each method). This allowed for a comparison between methods without daily variation being a confounding factor, and also allowed the assessment of intra-user reliability.

Skinfold measure (SFM)

Skinfold thickness (millimetres) measures were taken from three anthropometric sites with three measures taken on each of the sites. Anthropometric sites for males consisted of the chest, abdomen and thigh [9] and triceps, suprailiac, and thigh for females [10].

The equations for the skinfold is the Jackson Pollock 3-site method and the Siri's percentage body fat equation [25], are below.

Males

$$\text{Body Density} = 1.109 - 0.0008267*\text{sum} + 0.0000016*\text{sum}^2 - 0.0002574*\text{age}$$

$$\text{Percentage fat} = [(495/\text{Body Density}) - 450]$$

Females

$$\text{Body Density} = 1.099 - 0.0009929*\text{sum} + 0.0000023*\text{sum}^2 - 0.0001392*\text{age}$$

$$\text{Percentage fat} = [(495/\text{Body Density}) - 450]$$

LeanScreen (LSA)

LSA requires the investigator to enter stature and sex prior to any measurements. LSA requires three images to estimate body composition; a calibration image for the height of the participant, an image of the participant from the sagittal plane and an image of the participant from the frontal plane (Figure 1). Participants remained clothed as per the software developer's instructions. LSA requires

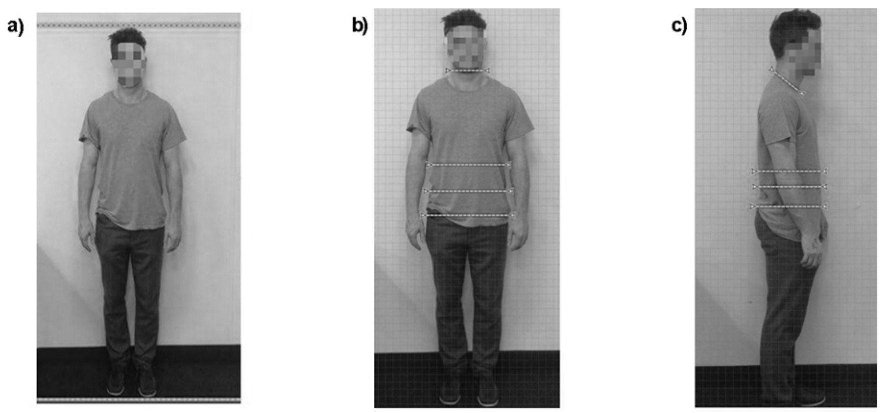

Fig. 1. Images used by LSA to estimate body composition. a) Shows the calibration procedure. b) Shows the frontal view with widths for neck, abdomen width (halfway between the navel and xiphoid process), abdomen width (level with the navel) and the widest point at the hips. C) Shows the sagittal view with depths for the neck (base of the back of the neck to the base of front), abdomen width (halfway between the navel and xiphoid process), abdomen width (level with the navel) and then the hip at buttock protrusion

the user to digitise a range of widths (frontal) and depths (sagittal) between various anatomical landmarks. Figure 1 shows the widths and depths digitised by the user as per the software developer's instructions. An Apple iPad was used in this study, and readers should be aware that the LSA is not available for Android devices at this time.

Bioelectrical impedance (BIA)

BIA provided estimation of %BF using the Bodystat 1500 analyser, with adherence to the manufacturer's instructions (Bodystat 1500, Isle of Man, UK). Two electrodes were placed sideways on the foot. One electrode was placed directly where the second and third toe meet the foot. The second electrode was placed at the ankle, between the medial and lateral malleoli and parallel to the first electrode. A further two electrodes were placed sideways on the hand. One electrode was placed below the third knuckle of the middle finger. The second electrode was placed at the wrist between the styloid processes of the radius and ulna.

Statistical analysis

All statistical analyses were completed using IBM SPSS Statistics 22 (SPSS Inc., Chicago, IL). Central tendency and dispersion of the sample data are represented as the mean ± SD. Differences in estimated %BF between the methods were analysed via ANOVA with statistical significance set at $p \leq 0.05$. The data was tested for normal distribution quantitatively by ensuring Z scores were between –2 and 2, and qualitatively via Q-Q plots. Relative test-retest reliability was assessed via intra-class correlation coefficients (ICC) with 95% confidence intervals (CI). Absolute test-retest reliability was assessed using coefficient of variation (CV) and typical error of measurement (TEM). Bland-Altman plots were produced by plotting the average of each measure against the difference of each measure for each method.

Results

As outlined in Table 1, the estimated average %BF of each method was comparable with no significant differences between measures ($F = 2.446$, $p = 0.818$). ICC between measurements were as follows Skinfold – BIA 0.816 (0.607–0.913), Skinfold – LSA 0.641 (0.235–0.831), BIA – LSA 0.744 (0.455-0.880).

The relative test-retest reliability, as determined using ICC with 95% confidence intervals, was found to be high for each of the methods (LSA = 0.974 [0.945–0.987], SFM = 0.997 [0.994–0.999], BIA = 0.997 [0.993–0.999]). However, the absolute reliability between measures was higher in SFM and BIA (CV ≤ 1.07%, TE ≤ 0.37) compared to LSA (CV = 6.47%, TE = 1.6). A visual representation of the variance can be seen in the Bland-Altman plots (Fig. 2. A–C).

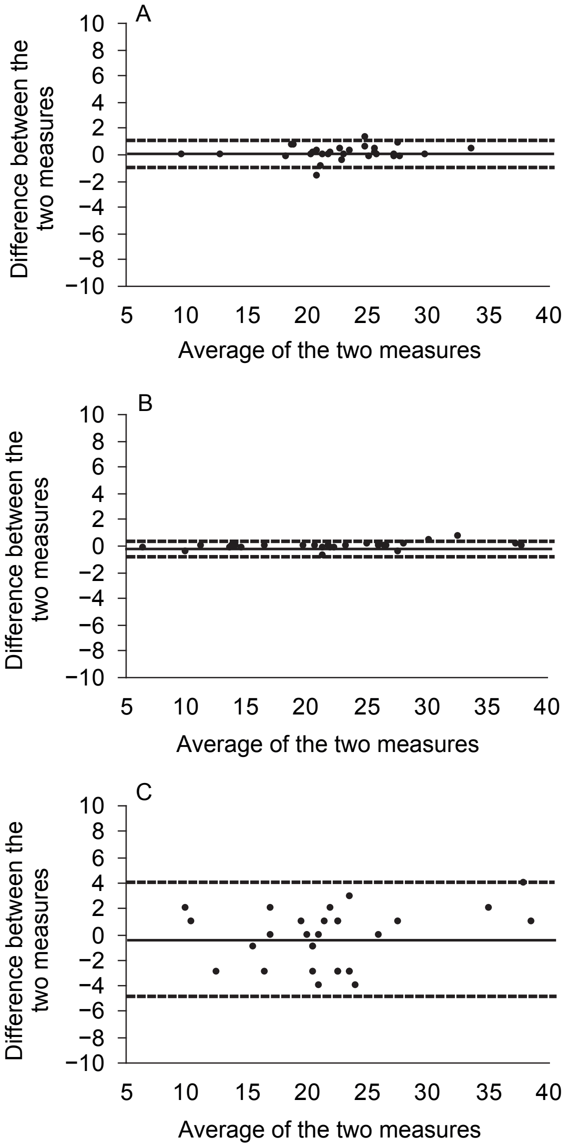

Fig. 2. Bland-Altman plots for SFM (A), BIA (B) and LSA (C) methods

Table 1. Mean ± SD estimated percentage body fat for each method

	Measurement 1	Measurement 2	Mean ± SD	ICC (95% CI)	CV	TEM
SFM	22.97 ± 4.83	22.86 ± 4.75	22.91 ± 4.78	0.997 (0.994–0.999)	1.07	0.37
BIA	22.26 ± 7.68	22.32 ± 7.57	22.29 ± 7.62	0.997 (0.993–0.999)	0.68	0.23
LSA	21.72 ± 7.10	22.07 ± 6.51	21.90 ± 6.72	0.974 (0.945–0.987)	6.47	1.6

Discussion

The aim of this investigation was to compare a tablet software application designed to estimate body fat percentage to other methods field based methods. A primary finding was that there were no significant differences between the average measures of estimated %BF for SFM, BIA and LSA ($F = 2.446$, $p = 0.818$).

Both the SFM and BIA demonstrated high relative and absolute test-retest reliability. SFM produced similar ICC as those reported by Macfarlane [15] (0.997 and 0.999 respectively) when using ISAK (International Society for the Advancement of Kinanthropometry) trained anthropometrists. It should be noted that Macfarlane's [15] investigation also examined within-day reliability in the same manner as this investigation. Relative consistency concerns the consistency of the position or rank of individuals in the group relative to others [27]. Atkinson and Nevill [2] conclude that practitioners should be cautious in the use of relative reliability to make inferences about the reproducibility of procedures and instruments, suggesting a measure of absolute reliability (e.g. CV) as this provides the degree to which repeated measures vary for individuals. The LSA demonstrated high relative test-retest reliability (ICC = 0.974) but limited absolute reliability as demonstrated in table 1 (CV = 6.47%, TEM = 1.6) and figure 2C. This study highlights dangers of misleading results if only relative reliability is reported.

The LSA application may demonstrate higher variance in comparison to SFM and BIA as it reports percentage body fat to the nearest whole number. This therefore makes LSA a less sensitive measure with potential implications. For example, Willis et al. [28] found a reduction of 0.65% in body fat to be a significant difference when examining the effects of a resistance training intervention on overweight and obese adults. It also cannot be discounted that digitising over clothing may have had an influence on the measurements, however we felt that it was important to use the LSA in accordance with manufacturer's instructions.

In terms of limitation, the authors acknowledge a lack of criterion measure such as Hydrostatic Weighing (HW) [3] and Dual Energy X-ray Absorptiometry (DXA/DEXA) [9]. However given the previously mentioned limited access for this equipment [11, 14], it was deemed appropriate to examine the software application against instruments with comparable access i.e. low-cost, convenience and portability [1]. Practitioners should always be cautious when interpreting percentage body fat results as all measurements are estimates, and field tests are likely to include some variance from 'gold-standard' laboratory methods. However Loenneke et al. [13] suggest that the validity of these field based methods may be of less practical importance than the reliability. The high relative and absolute test-retest reliability of the SFM and BIA procedures demonstrate that practitioners can be more confident that changes in data are true changes, as both (CV and TEM) measurement errors for SFM and BIA were below the recommended 2% limit [5]. The CV of measurements taken using LSA were above this threshold, suggesting extra care should be taken when interpreting the results.

To conclude, the LeanScreen^{TM} mobile application may offer an alternative field-test for practitioners. However, if it is used in practice, practitioners should measure individual variance to develop an understanding of minimal worthwhile change as it may not be suitable for a one-off measurement. This may be important as body fat is not constant, but rather shows time-relation variation [16].

Conflict of interest: Authors state no conflict of interest.

References

1. Andreoli A., Garaci F., Cafarelli F.P., Guglielmi G. (2016) Body composition in clinical practice. *Eur. J. Radiol.,* 85: 1461-1468. DOI: 10.1016/j.ejrad.2016.02.005.
2. Atkinson G., Nevill A.M. (1998) Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med.,* 26: 217-238. DOI: 10.2165/00007256-199826040-00002.
3. Colantonio E., Dâmaso A.R., Caranti D.A., Pinheiro M.M., Tufik S., Mello M.T.d. (2015) Clinical performance of 3-body fat measurements in obese adolescents 15 to 18 years-old. *Rev. Bras. Med.,* 72: 77-82.
4. Gholi Z., Heidari-Beni M., Feizi A., Iraj B., Askari G. (2016) The characteristics of pre-diabetic patients associated with body composition and cardiovascular disease risk factors in the Iranian population. *J. Res. Med. Sci.,* 21: 1-6. DOI: 10.4103/1735-1995.179888.
5. Gore C. (2000) Quality assurance in exercise physiology laboratories. Physiological testing for elite athletes (Australian Sports Commission). *Human Kinetic*s, Champaign.
6. Habibi E., Soury S., Zadeh A.H. (2013) Precise evaluation of anthropometric 2D software processing of hand in comparison with direct method. *J. Med. Signals Sensors,* 3: 256-261.
7. Hung P.C.-Y., Witana C.P., Goonetilleke R.S. (2004) Anthropometric measurements from photographic images. *Computing Systems,* 29: 764-769.
8. Hussain Z., Jafar T., uz Zaman M., Parveen R., Saeed F. (2014) Correlations of skin fold thickness and validation of prediction equations using DEXA as the gold standard for estimation of body fat composition in Pakistani children. *BMJ Open,* 4: e004194. DOI: 10.1136/bmjopen-2013-004194.

9. Jackson A.S., Pollock M.L. (1978) Generalized equations for predicting body density of men. *Brit. J. Nutr.,* 40: 497-504.
10. Jackson A.S., Pollock M.L., Ward A. (1979) Generalized equations for predicting body density of women. *Med. Sci. Sport Exerc.,* 12: 175-181.
11. Kälvesten J., Lui L.-Y., Brismar T., Cummings S. (2016) Digital X-ray radiogrammetry in the study of osteoporotic fractures: Comparison to dual energy X-ray absorptiometry and FRAX. *Bone,* 86: 30-35. DOI: 10.1016/j.bone.2016.02.011.
12. Karlen W., Garde A., Myers D., Scheffer C., Ansermino J.M., Dumont G.A. (2015) Estimation of respiratory rate from photoplethysmographic imaging videos compared to pulse oximetry. *IEEE J. Biomed. Health Informatics,* 19: 1331-1338. DOI: 10.1109/JBHI.2015.2429746.
13. Loenneke J.P., Barnes J.T., Wilson J.M., Lowery R.P., Isaacs M.N., Pujol T.J. (2013) Reliability of field methods for estimating body fat. *Clin. Physiol. Funct. Imaging,* 33: 405-408. DOI: 10.1111/cpf.12045.
14. Lowry D.W., Tomiyama A.J. (2015) Air displacement plethysmography versus dual-energy x-ray absorptiometry in underweight, normal-weight, and overweight/obese individuals. *PloS One*, 10(1): e0115086. DOI: 10.1371/journal.pone.0115086.
15. Macfarlane D.J. (2007) Can bioelectric impedance monitors be used to accurately estimate body fat in Chinese adults? *Asia Pacific J. Clin. Nutr.,* 16: 66-73.
16. Mazzoccoli G. (2016) Body composition: Where and when. *Eur. J. Radiol.,* 85: 1456-1460.
17. Moon J. (2013) Body composition in athletes and sports nutrition: An examination of the bioimpedance analysis technique. *Eur. J. Clin. Nutr.,* 67: S54-S59. DOI: 10.1038/ejcn.2012.165.
18. Ng B., Hinton B., Fan B., Kanaya A., Shepherd J. (2016) Clinical anthropometrics and body composition from 3D whole-body surface scans. *Eur. J. Clin. Nutr.,* in press. DOI: 10.1038/ejcn.2016.109.
19. Ockendon M., Gilbert R.E. (2012) Validation of a novel smartphone accelerometer-based knee goniometer. *J. Knee Surgery,* 25: 341-346. DOI: 10.1055/s-0031-1299669
20. Oeffinger D.J., Gurka M.J., Kuperminc M., Hassani S., Buhr N., Tylkowski C. (2014) Accuracy of skinfold and bioelectrical impedance assessments of body fat percentage in ambulatory individuals with cerebral palsy. *Dev. Med. Child Neurol.,* 56: 475-481. DOI: 10.1111/dmcn.12342.
21. Otter S.J., Agalliu B., Baer N., Hales G., Harvey K., James K., Keating R., McConnell W., Nelson R., Qureshi S. (2015) The reliability of a smartphone goniometer application compared with a traditional goniometer for measuring first metatarsophalangeal joint dorsiflexion. *J. Foot Ankle Res.,* 8: 1. DOI: 10.1186/s13047-015-0088-3.
22. Peart D.J., Shaw M.P., Rowley C.G. (2014) Validity of freely available mobile applications for recording resting heart rate. *Ann. Biol. Res.,* 5: 11-15.
23. Peart D.J., Shaw M.P., Rowley C.G. (2015) An investigation into a contactless photoplethysmographic mobile application to record heart rate post-exercise: Implications for field testing. *Biomed. Hum. Kinet.,* 7: 95-99. DOI: 10.1515/bhk-2015-0015.
24. Reyes B., Reljin N., Kong Y., Nam Y., Chon K. (2016) Tidal volume and instantaneous respiration rate estimation using a smartphone camera. *IEEE J. Biomed. Health Inform.*, 2168-2194. DOI: 10.1109/JBHI.2016.2532876.
25. Siri W. (1956) The gross composition of the body; In: Lawrence J.H., Tobias C.S. (eds): Biological and Medical Physics. New York, Academic Press.
26. Tompuri T.T., Lakka T.A., Hakulinen M., Lindi V., Laaksonen D.E., Kilpeläinen T.O., Jääskeläinen J., Lakka H.M., Laitinen T. (2015) Assessment of body composition by dual-energy X-ray absorptiometry, bioimpedance analysis and anthropometrics in children: the Physical Activity and Nutrition in Children study. *Clin. Pysiol. Funct. Imaging,* 35: 21-33. DOI: 10.1111/cpf.12118.
27. Weir J.P. (2005) Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J. Strength Cond. Res.*, 19: 231-240. DOI: 10.1519/15184.1.
28. Willis L.H., Slentz C.A., Bateman L.A., Shields A.T., Piner L.W., Bales C.W., Houmard J.A., Kraus W.E. (2012) Effects of aerobic and/or resistance training on body mass and fat mass in overweight or obese adults. *J. Appl. Physiol.,* 113: 1831-1837. DOI: 10.1152/japplphysiol.01370.2011

Received 02.03.2017
Accepted 07.06.2017

Acknowledgments

The authors wish to thank all the participants who took the time to volunteer for this study. This study received no external funding and there are no competing interests.