Developing and Evaluating Non-invasive Healthcare Technologies for a Group of Female Participants from a Socioeconomically Disadvantaged Area

Eman Awad
Malmo Universitet
Rathi Ramji
Malmo Universitet
Stefan Cirovic
Malmo Universitet
Margareta Rämgård
Malmo Universitet
Anders Kottorp
Malmo Universitet
Sergey Shleev (sergey.shleev@mau.se)
Malmö University https://orcid.org/0000-0001-6421-2158

Research

Keywords: Socially disadvantaged community, Healthcare, Non-invasive biomedical analysis, Quality of Life-BREF survey

Posted Date: April 12th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-357235/v1

Version of Record: A version of this preprint was published at Scientific Reports on December 1st, 2021. See the published version at https://doi.org/10.1038/s41598-021-03262-3.

Abstract

Background When compared to the general population, socioeconomically disadvantaged communities frequently experience compromised health. Monitoring the divide is challenging since in general, standardized biomedical tests are linguistically and culturally inappropriate. The aim of this study was to develop a novel healthcare technology for its usage in socioeconomically disadvantaged areas.

Methods A unique mobile biomedical testbed based on non-invasive analysis, accompanied with the World Health Organization Quality of Life survey, was developed. This healthcare approach was used in Lindängen, a socioeconomically disadvantaged neighborhood in Malmö, which has been listed as one of the twelve most vulnerable neighborhoods in Sweden.

Results The less intrusive biomedical approach, compared to conventional setups used, *e.g.*, wrist blood pressure monitoring, bioimpedance analysis and cardiovascular diagnostics, non-invasive determination of blood bioanalytes, was highly appreciated by the participants, *i.e.*, 39 female volunteers of Middle Eastern origin. Surprisingly, the collected biomedical data illustrated that the apparent health of the participants from Lindängen was comparable to the general Swedish population. The Quality of Life-BREF survey, used to gather information regarding subjective health perceptions within the cohort, combined with advanced statistical data analysis, revealed statistically significant correlations between perceived health and biomedical data. Even though the dependences found were complex, the recognition of which is essential in further research.

Conclusions Our results validate the potential of non-invasive technologies in combination with advanced statistical analysis, especially when combined with linguistically and culturally appropriate healthcare methodologies, allowing participants to appreciate the significance of the different parameters to evaluate and monitor aspects of health.

Background

Non-invasive healthcare technologies are an important part of research and development nowadays due to their low cost and convenience they offer to both healthcare receivers and providers [1]. In addition to traditional non-invasive technologies, which are known and used for ages, *e.g.*, electrocardiography [2; 3], many other non-invasive instruments have been developed, such as cardiovascular diagnostic systems [4], bioimpedance based scales [5; 6], and even non-invasive blood analyzers to measure not only physical parameters of the body, but also sentinel chemicals in blood, *e.g.*, hemoglobin (Hb) [7], oxygen [8], and glucose (Glu) [9; 10]. On the one hand, some of non-invasive chemical blood analyzers, *e.g.* glucometers, are not precise and reliable devices [11]. On the other hand, pulse-oximeters are widely used in acute and critical care nowadays [12]. Moreover, due to above mentioned advantages, when developed further, non-invasive chemical blood analyzers might be considered as powerful tools for subgroups with greater healthcare needs, such as infants and elderlies, as well as socially disadvantaged populations. These subgroups frequently experience compromised health in comparison to the majority population owing to their poor living conditions. They are often exposed to different problems, such as social exclusion, discrimination and poverty. Socioeconomically disadvantaged populations are also at a higher risk for mental health issues, as well as physical health conditions, such as obesity and hypertension due to poor lifestyle [13]. However, serious challenges, mainly distrust, to assess health in underserved areas using conventional setups are also firmly established [14].

Lindängen is a socioeconomically disadvantaged neighborhood in Malmö city located in the South of Sweden. The Swedish Intelligent Unit has enlisted Lindängen as one of twelve vulnerable neighborhoods in country. In the recently published report challenges in Lindängen, such as high rate of crime, low education levels, unemployment, and poor health among citizens in the neighborhood, has been reflected [15]. The study reported herein has been conducted inside a large project ”Health promotion in collaboration”, which is based on community-based participatory research (CBPR) [16] and aims to promote health among citizens in Lindängen. An important aspect in CBPR approach is to involve the participants within the various stages of the research process through dialogue and reflection, which also includes joint work with participants in the data gathering process to evaluate health outcomes [17]. Such a dialogue with the citizens of Lindängen showed that they perceived a lack of access to health care, specifically the possibility to measure their health at a low cost, which would help them understanding their own physical health status [18]. Therefore, it was decided to specifically focus on incorporating non-invasive healthcare technologies in the project to map physical health of participants. Non-invasive healthcare technologies address the factors that affect the degree of comfort the user experiences during measurements, including social aspects, which have been little or even completely unexplored.

Materials And Methods

Administration of health outcomes

The participants were instructed to remain calm and quite before and during the biomedical measurements. The participants were not asked to fast prior to the measurements. There was over 95% attendance rate in all sessions both when the surveys were administered, as well as when biomedical measurements were performed. The participants also received feedback on their health outcomes by the trained biomedical analysists who performed the data collection in their mother language, most often Arabic, with the support of a health promoter who are representatives from the community [18].

Biomedical measurements

Systolic and diastolic blood pressures (SBP and DBP, respectively) and resting heart rate (RHR) were measured using an iHealth Sense wireless wrist monitor from iHealth Labs Inc. (Sunnyvale, California, USA). The monitor was placed on the participants’ wrist.

Bioelectrical impedance analysis was performed using a bioimpedancometer MC780MA from Tanita (Tokyo, Japan). This analyzer differentiates between the individuals’ body fat, muscle mass (MM) and water mass, as well as automatically calculates body mass index (BMI) and metabolic age. The participants were instructed to stand on the device with bare feet placed on the electrode platform until their body weight was displayed. Then, the participants were instructed to hold the handlebars with their arms straight down until the remaining parameters were displayed. Prior to the analysis, the participants' basic parameters (gender, height and body type) were entered into the memory of the device.

Vascular age (VA) and stress index (SI) were determined using an AngioScan-01 from AngioScan-Electronics (Moscow, Russia). The device was placed on the participants' right index finger.

Glu and Hb concentrations in blood were determined non-invasively using a BG20 blood glucose meter from Yones Toptech (Shenzhen, China). The device was placed on the participants' right index finger, and the time interval during which the participant had consumed food most recently was entered.

Health survey

The WHO (World Health Organization) Quality of Life-BREF survey was used to gather information regarding subjective health perceptions within the sample [19]. The validity and reliability of the instrument has been tested in extensively internationally and is available in 20 different languages including Swedish [19] and Arabic [20]. The survey contains twenty-six questions and measure four broader health areas *i.e.*, physical health, mental health, social relations and environmental health domains, as well as two global items. A raw score of each domain and item can be calculated and transferred into range between 0-100 and 0-5, respectively. Higher scores denote higher health-related quality of life (QoL) [19].

Data analysis

Relationships between self-reported health measures and biomedical measures were analyzed using univariate (nonparametric correlation statistics) and multivariate (parametric correlation statistics) regression analyses employing software packages SPSS Statistics from IBM Corp. (Armonk, New York, USA) and Wolfram Mathematica software package from Wolfram Research (Champaign, Illinois, USA), respectively. The default significance level in all calculations was 0.05. During multivariate regression analysis models were built using all data points acquired in the investigation. Initial model was based on all variables and was further improved by discarding variables or adding nonlinearities. All statistical properties of models and residuals are described alongside with the results.

Results

First, a unique biomedical testbed based on non-invasive devices was designed. In order to develop appropriately tailored health tests for participants from Lindängen, specific devices were used, which were less intrusive compared to conventional devices. For instance, blood pressure was measured on the wrist instead of the upper arm, Fig. 1(a). Measurements of body composition were performed using bioelectrical impedance analysis instead of using tape measurements, thus limiting direct body contact to a minimum, Fig. 1(b). Additional non-invasive devices were also included in the health test, *viz*. the cardiovascular diagnostic complex AngioScan-01, Fig. 1(c), and the non-invasive blood analyzer, BG20, Fig. 1(d), to achieve a comprehensive non-invasive biomedical test.

Second, for biomedical test 56 volunteers from Lindängen for were identified. 17 of these participants did not fully complete the biomedical tests and were therefore excluded from data analysis. Thus, a total of 39 female volunteers, aged 25-77 years, participated in this study. Participants were of Middle Eastern origin (Supplementary Information, Supplementary Table S1).

Biomedical tests revealed that 25.6% (n=10) of the participants had blood pressures outside of the reference interval, Fig. 2(a)-3(b), whereas only 2.6% (n=1) had a RHR outside of the reference interval, Fig. 2(c). The reference intervals for SBP and DBP, as well as RHRs, were defined according to Refs. [21; 22].

In accordance with the literature, overweight and obesity are defined by BMIs of $\geq$25 kg/m^2 and $\geq$30 kg/m^2, respectively [23]. Thus, 25.6% (n=10) of the participants were considered to be overweight and 51.3% (n=20) were obese, Fig 3.

More than half of the participants had body fat percentages above the reference intervals, Figs. 4(a)-4(c), *i.e.* 21-33% of body fat for 20-39 year olds, 24-34% of body fat for 40-59 year olds, and 25-36% of body fat for 60-79 year old individuals [24].

VA and SI were also determined based on RHR, stiffness of blood vessels, and differences of arterial pressure [25] using the professional dual-channel cardiovascular complex, Fig. 5. According to the manufacturer, the reference interval for the stress index is 0-150 units, whereas VA should be equal to or below the age of the participant [25]. It was found that many volunteers had both parameters above the cut-off values, Fig. 5.

Moreover, Hb and Glu concentrations in blood were determined non-invasively, Fig. 6. Interestingly, almost all obtained values were within the reference intervals, 120-160 g/L for Hb and 2.8-11.1 mM/L for Glu [26].

In parallel, the Quality of Life-BREF survey was distributed among the participants. Table 1 shows the obtained QoL scores. All the mean domain scores were around the fifty-percentage mark, meaning that the sample were distributed in relative equal proportions around the cut-off level for satisfaction in quality of life. However, about half of the participants (n=17) had domain scores lower than the satisfactory level.

Table 1 QOL scores of participants

WHOQOL-BREF score (scale)	Mean score (SD)	Score range
Physical health domain	54.3 (19.3)	0 – 100
Psychological domain	54.0 (15.9)	0 – 100
Social relationships domain	63.8 (18.8)	0 – 100
Environmental domain	56.0 (16.7)	0 – 100
Health related quality of life global item	3.5 (0.9)	0 – 5
Health satisfaction global item	3.9 (1.1)	0 – 5

Third, detailed statistical analysis of the data was performed. In absence of a relevant model, nonparametric correlation statistics was initially exploited. This analysis (Spearman's and Kendal's rank tests) revealed no significant correlation between the four QoL domain scores/two of the global items and biomedical metrics. This was unsurprising since the dependence between perceived health and biomedical metrics is *a priori* complex. In other words, it is hard to envision strong linear dependences between participant-perceived QoL scores and individual biomedical parameters, such as body composition parameters, RHR, blood pressure, etc, using a univariate regression analysis. Thus, multivariate regression analysis of all the data collected was carried out. The identification of variables, which statistically significantly correlate (p-value < 0.05) was performed using a meta-modelling approach. As expected, linear multi-variable models failed to provide any statistically significant correlations. Indeed, a 2-term set of all possible models with inclusion of linear, inverted, squared, and pairwise multiplied variables was investigated to identify statistically important variables. A set of identified statistically significant variables, which are presented in Supplementary Table S2, was used to build all possible 4-term models, which were tested, and the best model was selected for each case.

The social relationships domain and health related QoL global item scores have no statistically significant correlations with variables. The best model found to describe physical health domain scores is presented in Equation 1, while the statistical properties of the model are provided in ANOVA Supplementary Table S3.

$$-22.2452 + 1799.6/BMI + 0.0157277 \cdot FM \cdot VA - 0.000567556 \cdot VA \cdot SI \qquad (1)$$

As one can see from Supplementary Table S3, all coefficients are statistically significant. On the one hand, the model shows that larger BMI lowers expected physical health domain scores. On the other hand, surprisingly, larger FM and VA, rise physical health domain scores. However, it should be noted that there is a linear correlation between variables FM and BMI, and hence it may be a manifestation of the approximate quadratic dependence on BMI. The SI in synergy with VA lower physical health domain scores. The physical health domain scores predicted by the model have a 0.533 statistically significant correlation coefficient with a p-value of 0.00048.

The best model found to describe psychological domain scores is presented in Equation 2, while the statistical properties of the model are provided in ANOVA Supplementary Table S4.

$$-20.2236 - 1092.97/Age + 2257.35/BMI + 0.0218865 \cdot FM \cdot BMI \qquad (2)$$

As one can see from Supplementary Table S4, all coefficients are statistically significant. Age tends to lower psychological domain scores, however, with increasing age, the negative impact on psychological domain scores is attenuated. Psychological domain scores are increased by smaller BMIs and by a synergistic interaction of BMI with FM. The psychological domain scores predicted by the model have a 0.606 statistically significant correlation coefficient with a *p*-value of 0.000043.

The best model found to describe environmental domain scores is presented in Equation 3, while the statistical properties of the model are provided in ANOVA Supplementary Table S5.

$$70.5533 - (8.39801 \cdot RHR)/Age \qquad (3)$$

As one can see from Supplementary Table S5, the coefficient is statistically significant. Age tends to inversely lower environmental domain scores and the effect is attenuated with age and increases with RHR. The environmental domain scores predicted by the model have a weakly statistically significant correlation coefficient of 0.32 with a *p*-value of 0.046.

The best model found to describe health satisfaction is presented in Equation 4, while the statistical properties of the model are provided in ANOVA Supplementary Table S6.

$$-2.73262+84.1044/FM+0.000445315\ Age \cdot FM+0.000449529\ SBP \cdot FM \qquad (4)$$

As one can see from Supplementary Table S6, all calculated coefficients are statistically significant. FM has an inverse positive effect on health satisfaction scores, which are synergistically weakly affected by Age and SBP. The health satisfaction scores predicted by the model have a 0.612 statistically significant correlation coefficient with a *p*-value of 0.000035.

Discussion

First, the unique mobile testbed based on non-invasive technologies developed in the current studies was less intrusive compared to conventional methods due to minimizing of physical contact and exposure of skin, which was beneficial for individuals with specific backgrounds *e.g.*, from the Middle East. Moreover, portability allowed us to perform the test in the immediate region of interest, *i.e.*, Lindängen.

Second, biomedical studies revealed high SIs measured in more than 50% of the volunteers, which is an extreme situation for an average apparently healthy population. On the one hand, this is not surprising since lower socioeconomic status has been linked to long-term stress, which can manifest in individuals as physiological stress [27]. Moreover, it is believed that low socioeconomic status harms health through dysregulation of the physiological stress response systems [28]. On the other hand, one of the strong indicators of a high stress level with a high risk of chronic diseases is higher RHR. Several studies have reported on the association between elevated RHR and cardiovascular mortality [29; 30]. However, in our studies almost all participants had a RHR within the reference interval, Fig. 3(c), and their vascular age was scattered, in comparison with their real age, Fig. 5(a), which is expected in an on average apparently healthy population. It should be emphasized that even though non-invasive determination of Glu and Hb concentrations in blood were included in biomedical analyzes, due to the current lack of evidence regarding the ability of the device to determine these bioanalytes accurately, one should consider the results from non-invasive measurements with serious cautiousness, Figs. 6(a) & 6(b).

Third, certain medical conditions of the participants from Lindängen were directly compared to the general Swedish population (Table 2). The overweight incidence was remarkably lower for the participants from Lindängen, compared to the Swedish population [31], whereas Lindängen's participants had a higher incidence of obesity. According to the literature, hypertension is defined by a SBP of ≥140 mmHg or DBP of ≥90 mmHg [32]. Taken these values into account one could conclude that the level of hypertension among the participants was slightly higher compared to the Swedish population [33].

Table 2 Comparison of medical conditions in Lindängen to the general Swedish population

	General Swedish population (%)	Lindängen, Malmö (%) (n)
Overweight	52.4	25.6 (n=10)
Obesity	20.4	51.3 (n=20)
Hypertension	22.3	25.6 (n=10)

Surprisingly, the mean scores of psychological and physical health domains were very close to each other despite of high SIs measured in more than 50% of the volunteers. Moreover, significant correlation between psychological domain scores and SI was not observed, whereas the SI in synergy with VA lowered physical health domain scores.

As stated above, the participants from Lindängen were a uniform group of female volunteers from the Middle East. On the one hand and to some extent, the ethnicity of the participants represents the area due to the high number of residents in Malmö who are not born in Sweden [34]. On the other hand, the participants were not ideal representatives of the area due to the uniformity in gender and old age bias. The ratio between female and male residents in Malmö is *ca.* 50/50 [34]. Moreover, almost half of the residents in Malmö are under 35 years, whereas the average age among the participants was 49 years (Table 1). Thus, one should consider that biomedical conclusions made in the current studies could possibly understate the general health status of people in Lindängen. In other words, the small sample from this socioeconomically disadvantaged community makes the interpretations from Table 2 more indicative than conclusive.

Last but not least, comprehensive statistical analysis of all the results was carried out. To the best of our knowledge, this is the first study in the field of CBPR, where multivariate non-linear regression analysis of health outcomes was exploited. Many interesting correlations between perceived health-related QoL and biomedical metrics were disclosed, *i.e.*, between physical health domain scores, BMI, FM, and VA; psychological domain, Age, BMIs, and FM; environmental domain, Age and RHR; health satisfaction, FM, Age, and SBP. It is concluded that strong relationships between perceived health and biomedical metrics do exist, and even though they are very complex, the recognition of which is essential. The social relationships domain and self-reported QoL scores have no statistically significant correlations with variables. However, it should be noted, that all models were found from a limited subset of variables and more interesting correlations could be found by expanding the number of terms used in the evaluation of the models. This, of course, is computationally costly, and the model space increases factorially with the number of terms included in a model.

Studies exploring the relationships between comprehensive biomedical assessments and self-reported WHO QoL-BREF scores are few and far between. Previous investigations have only examined the relationships between measurements of blood pressure or BMI in general population groups using univariate regression analysis [7; 35-37]. Nevertheless, our results are somehow in line with a previous study describing a relationship between BMI and general health satisfaction, where the strength of the correlation coefficient particularly among older women was low (r=0.025) [7; 35-37]. According to earlier studies, women below 55 years of age are more concerned about their body weight, BMI, and body image compared to older women. The current study included women with a median age of 47 years, which may explain the stronger correlation between health satisfaction and body composition in this group of women [38]. Most participants in this study singled out weight loss as a motivation to participate in the physical activity intervention that was to follow the biomedical assessments. Participants seemed to be more aware of the significance of body weight in relation to their health, in contrast to the lack of understanding of the other complex measurements performed in this study. Such an awareness can be tapped in future health promotional efforts to socioeconomically disadvantaged groups to address obesity and overweight related problems.

The implementation of the non-invasive testbed in Lindängen was highly appreciated by the participants, as indicated by the high attendance rate in the data gathering process. The participants realized that the different health parameters tested could easily be used to monitor their health in relation to the risks of developing different diseases including cardiovascular disorders. Also, participants were excited about the health tests since they expressed a lack of trust in the health system in general in Sweden, and had no wish to be analyzed using conventional setups. Since they had been offered the time and personal contact when being tested, and were also given the opportunity to learn the significance of measured health parameters using their native language, the participants appreciated the health test even more. Taking these findings in consideration with the results from the current work, the evidence of using non-invasive health tests for people in a socioeconomically challenged suburb in Sweden seems to be supportive from several perspectives in relation to evaluating health descriptors.

The additional findings, when comparing participant results with generic health data from Sweden, also indicate that health is to be considered as a multifaceted phenomenon that needs to be approached using several perspectives and data gathering methods. Given the evidence from this study, health should never be summarized or evaluated relying on a single circumstance, as this may lead to very different conclusions regarding the overall participant health status. Rather, a more elaborate approach using both objective and subjective health parameters, as well as qualitative data targeting health related descriptors, is preferable to gauge and understand the complex phenomenon of health in these communities.

Conclusion

The uniquely designed testbed based on non-invasive assessment tools, accompanied with the WHO QoL survey, was implemented in a socioeconomically disadvantaged community. The application of the testbed in Lindängen was highly appreciated by the participants. The findings of the current study illustrate that the physical health of the participants from Lindängen, as evident from biomedical parameters, was comparable to the general Swedish population, apart from a higher number of obese individuals and fewer cases of overweight. Using multivariate non-linear regression analysis interesting correlations between perceived health and biomedical metrics were disclosed. The results from this study strongly suggest the need to assess health using multiplex methods along with different mathematical/statistical approaches, especially in socially disadvantaged communities. Thus, future efforts should be devoted towards the automatization of data gathering process, proper data handling and storage following current General Data Protection Regulation rules, as well as advance analysis of the collected data using different mathematical/statistical approaches, including the development and exploitation of advanced Artificial Intelligence based diagnostic systems.

List Of Abbreviations

BMI: Body mass index

CBPR: Community-based participatory research

DBP: Diastolic blood pressure

FM: Fat mass

Glu: Glucose

Hb: Hemoglobin

MM: Muscle mass

QoL: Quality of life

RHR: Resting heart rate

SBP: Systolic blood pressure

SI: Stress index

VA: Vascular age

WHO: World Health Organization

Declarations

Ethics approval and consent to participate

Prior to initiation, the Regional Ethical Committee in Lund approved this study (DNR 2018-384 and DNR 2019-01741). All participants were initially informed that they would take part in a research process with the purpose to investigate new technologies in their area, Lindängen, Malmö, Sweden. Participation was voluntary and participants were informed that they could leave the study at any time. Written information on the research process was also provided and participants were asked to sign an informed consent sheet. All materials collected were marked by code and kept confidential and shall be accessed only by the research team members.

Consent for publication

All participants were informed that they would take part in a research process, the results of which might be published. Consents forms are available upon reasonable request.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research was funded by VINNOVA (projects 2016–00421 and 2017–01272), primarily for the establishment of the health promoting platform. Research conducted within this platform was funded by Malmö University, *viz.* MultiSens and COVID-19 projects.

Authors' contributions

RR, EA, and SC gathered all the data, performed initial data analysis, and prepared the first draft of the manuscript. AK and SS performed detailed statistical analysis. MR, AK, and SS conceived of the study, participated in the design of the study and contributed to the final version of the manuscript. All authors read and approved the final manuscript.

References

1. Yamani, A. Z., Alqahtani, F. M., Alshahrani, N. S., Alzamanan, R. M., Aslam, N., Algherairy, A. S., & Ieee. (2019). A proposed noninvasive point-of-care technique for measuring hemoglobin concentration. 2019 International Conference on Computer and Information Sciences, 487-490.
2. Howell, J. D. (1991). Diagnostic technologies - X-rays, electrocardiograms, and cat-scans. Southern California Law Review, 65(1), 529-564.
3. Fye, W. B. (1994). A history of the origin, evolution and impact of electrocardiography. American Journal of Cardiology, 73(13), 937-949.
4. Bonetti, P. O., Pumper, G. M., Higano, S. T., Holmes, D. R., Kuvin, J. T., & Lerman, A. (2004). Noninvasive identification of patients with early coronary atherosclerosis by assessment of digital reactive hyperemia. Journal of the American College of Cardiology, 44(11), 2137-2141.
5. Lukaski, H. C., Johnson, P. E., Bolonchuk, W. W., & Lykken, G. I. (1985). Assessment of fat-free mass using bioelectrical impedance measurements of the human body. American Journal of Clinical Nutrition, 41(4), 810-817.
6. Khalil, S. F., Mohktar, M. S., & Ibrahim, F. (2014). The theory and fundamentals of bioimpedance analysis in clinical status monitoring and diagnosis of diseases. Sensors, 14(6), 10895-10928.
7. Barker, S. J., Shander, A., & Ramsay, M. A. (2016). Continuous noninvasive hemoglobin monitoring: A measured response to a critical review. Anesthesia and Analgesia, 122(2), 565-572.
8. Taylor, M. B., & Whitwam, J. G. (1986). The current status of pulse oximetry - Clinical value of continuous noninvasive oxygen-saturation monitoring. Anaesthesia, 41(9), 943-949.
9. Tierney, M. J., Tamada, J. A., Potts, R. O., Jovanovic, L., Garg, S., & Cygnus Res, T. (2001). Clinical evaluation of the GlucoWatch (R) biographer: a continual, non-invasive glucose monitor for patients with diabetes. Biosensors & Bioelectronics, 16(9-12), 621-629.
10. Caduff, A., Dewarrat, F., Talary, M., Stalder, G., Heinemann, L., & Feldman, Y. (2006). Non-invasive glucose monitoring in patients with diabetes: A novel system based on impedance spectroscopy. Biosensors & Bioelectronics, 22(5), 598-604.
11. Smith, J. L., 2006, "The pursuit of noninvasive glucose: "Hunting the deceitful Turkey" Seventh Edition," NIVG Consulting, LLC, Portland, OR, USA, 244 pp.
12. Ahrens, T., and Tucker, K., 1999, "Pulse oximetry," Department of Critical Care, Barnes-Jewish Hospital, St. Louis, Missouri, USA, pp. 87-98.
13. Welfare, A. I. o. H. a. (2016). Health across socioeconomic groups. Australia’s Health 15(199).

14. Melander, D., Melander, D., Sivarasu, S., Melander, D., Yekinni, I., Erdman, A., Melander, D., & Yunzhang, C. (2020). Diagnostics as the key to advances in global health: Proposed methods for making reliable diagnostics widely available. Journal of Medical Device, 14(1), 014702.
15. Nationella Operative Avdelningen, 2017, "Utsatta områden - Social ordning, kriminell struktur och utmaningar för polisen," https://polisen.se/siteassets/dokument/ovriga_rapporter/utsatta-omraden-social-ordning-kriminell-struktur-och-utmaningar-for-polisen-2017.pdf.
16. Israel, B. A., Eng, E., Schulz, A. J., & Parker, E. A. (Eds.). (2005). Methods in community-based participatory research for health: Jossey-Bass; 1st edition, 524 pp.
17. Abma Tineke, A., Cook, T., Ramgard, M., Kleba, E., Harris, J., & Wallerstein, N. (2017). Social impact of participatory health research: collaborative non-linear processes of knowledge mobilization. Educational Action Research, 25(4), 489-505.
18. Ramji, R., Carlson, E., Kottorp, A., Shleev, S., Awad, E., & Rämgård, M. (2020). Development and evaluation of a physical activity intervention informed by participatory research- a feasibility study. BMC Public Health, 20(112), 1-14.
19. Harper, A., Power, M., & Grp, W. (1998). Development of the World Health Organization WHOQOL-BREF quality of life assessment. Psychological Medicine, 28(3), 551-558.
20. Ohaeri, J. U., & Awadalla, A. W. (2009). The reliability and validity of the short version of the WHO quality of life instrument in an Arab general population. Annals of Saudi Medicine, 29(2), 98-104.
21. Carretero, O. A., & Oparil, S. (2000). Essential hypertension Part I: Definition and etiology. Circulation, 101(3), 329-335.
22. Cook, S. T., M. Schaub, M. C. Wenaweser, P. Hess, O. M. (2006). High heart rate: a cardiovascular risk factor? European Heart Journal, 27(20), 2387-2393.
23. Crunelle, C. L., Neels, H., Maudens, K., De Doncker, M., Cappelle, D., Matthys, F., Dom, G., Fransen, E., Michielsen, P., De Keukeleire, S., Covaci, A., & Yegles, M. (2017). Influence of body mass index on hair ethyl glucuronide concentrations. Alcohol and Alcoholism, 52(1), 19-23.
24. Total Row Fitness, 2018, "Healthy body fat ranges for adults," https://totalrowfitness.com/know-your-body-fat-total-row-explains-why-it-matters.
25. Angioscan Electronics LLC, 2014, "AngioScan-01P, AngioScan-01M: Personal device for cardiovascular system diagnosis," Moscow, Russia, 128 pp.
26. Cheng, C. K., Chan, J., Cembrowski, G. S., Van Assendelft, O. W. . (2004). Complete blood count reference interval diagrams derived from NHANES III: Stratification by age, sex, and race. Lab Hematology10(1), 42-53.
27. Zhang, A., Hughes, J. T., Brown, A., Lawton, P. D., Cass, A., Hoy, W., O'Dea, K., & Maple-Brown, L. J. (2016). Resting heart rate, physiological stress and disadvantage in Aboriginal and Torres Strait Islander Australians: analysis from a cross-sectional study. BMC Cardiovascular Disorders, 16, 36/31-36/38.
28. Le-Scherban, F., Brenner, A. B., Hicken, M. T., Needham, B. L., Seeman, T., Sloan, R. P., Wang, X., & Diez Roux, A. V. (2018). Child and adult socioeconomic status and the cortisol response to acute stress:

Evidence from the multi-ethnic study of atherosclerosis. Psychosomatic Medicine, 80(2), 184-192.
29. Palatini, P., & Jullius, S. (2004). Elevated heart rate: A major risk factor for cardiovascular disease. Clinical and Experimental Hypertension, 26(7-8), 637-644.
30. Palatini, P., Benetos, A., & Julius, S. (2006). Impact of increased heart rate on clinical outcomes in hypertension - Implications for antihypertensive drug therapy. Drugs, 66(2), 133-144.
31. World Health Organization (2016). Sweden - Diabetes country profiles. Geneva.
32. DeJongste, M. J. L. (2012). Hypertension (high blood pressure). https://www.neuromodulation.com/hypertension
33. World Health Organization (2015). Global Health Observatory data repository - Raised blood pressure (SBP ≥ 140 OR DBP ≥ 90), crude (%), Geneva.
34. Malmö stad, M. (2018). Statistik för Malmös områden. https://malmo.se/Fakta-och-statistik/Statistik-for-Malmos-omraden.html
35. Chung, P. K., Zhao, Y. N., Liu, J. D., & Quach, B. (2017). A canonical correlation analysis on the relationship between functional fitness and health-related quality of life in older adults. Archives of Gerontology and Geriatrics, 68, 44-48.
36. Herman, K. M., Hopman, W. M., & Rosenberg, M. W. (2013). Self-rated health and life satisfaction among Canadian adults: associations of perceived weight status versus BMI. Quality of Life Research, 22(10), 2693-2705.
37. Neumark-Sztainer, D., Paxton, S. J., Hannan, P. J., Haines, J., & Story, M. (2006). Does body satisfaction matter? Five-year longitudinal associations between body satisfaction and health behaviors in adolescent females and males. Journal of Adolescent Health, 39(2), 244-251.
38. Pruis, T. A., & Janowsky, J. S. (2010). Assessment of body image in younger and older women. Journal of General Psychology, 137(3), 225-238.

Figures

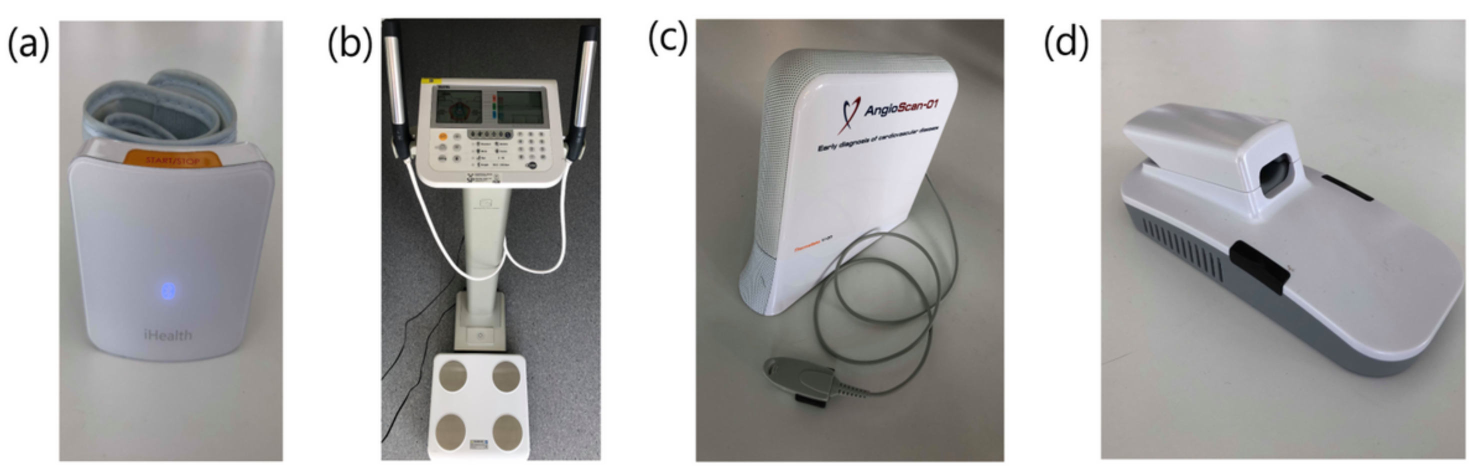

Figure 1

Non-invasive devices (a) blood pressure monitor iHealth Sense, (b) bioimpedance-meter Tanita MC780MA, (c) cardiovascular diagnostic complex AngioScan-01, (d) BG20 blood glucose meter.

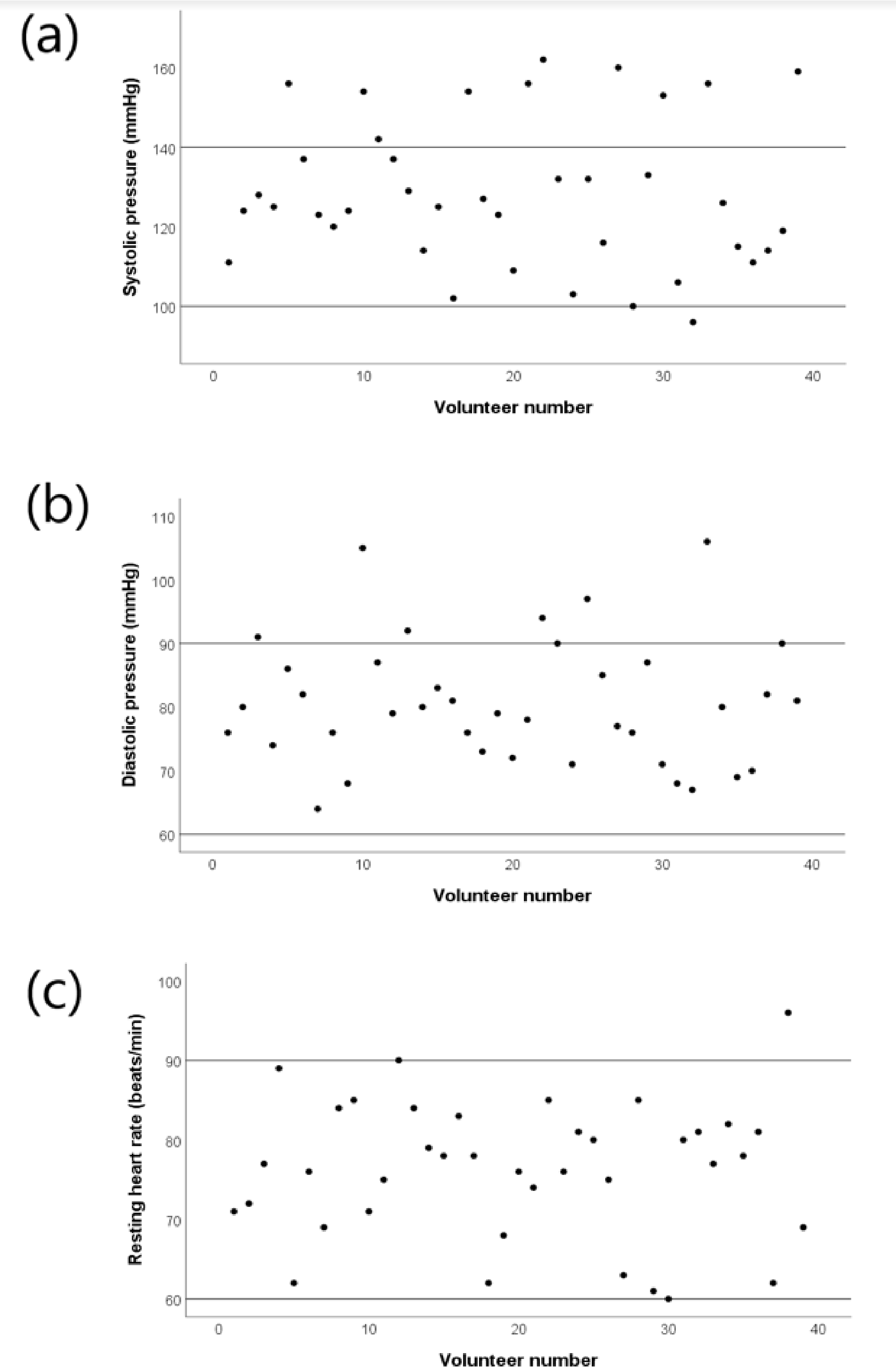

Figure 2

Blood pressures and resting heart rates. (a) systolic pressures, (b) diastolic pressures, and (c) resting heart rates.

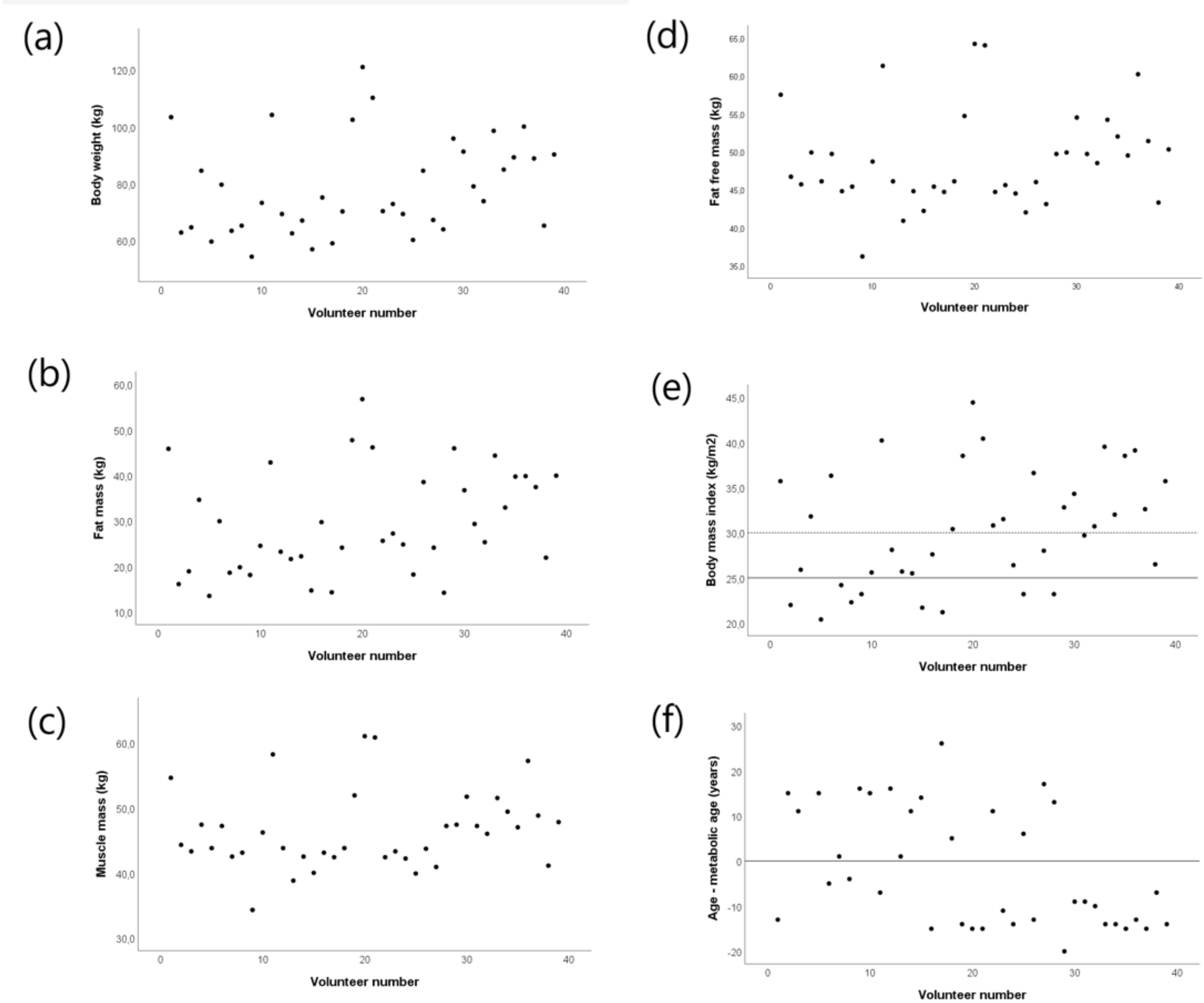

Figure 3

Body composition analysis (a) body weight, (b) fat mass, (c) muscle mass, (d) fat free mass, (e) body mass indexes, and (f) difference in real and metabolic ages.

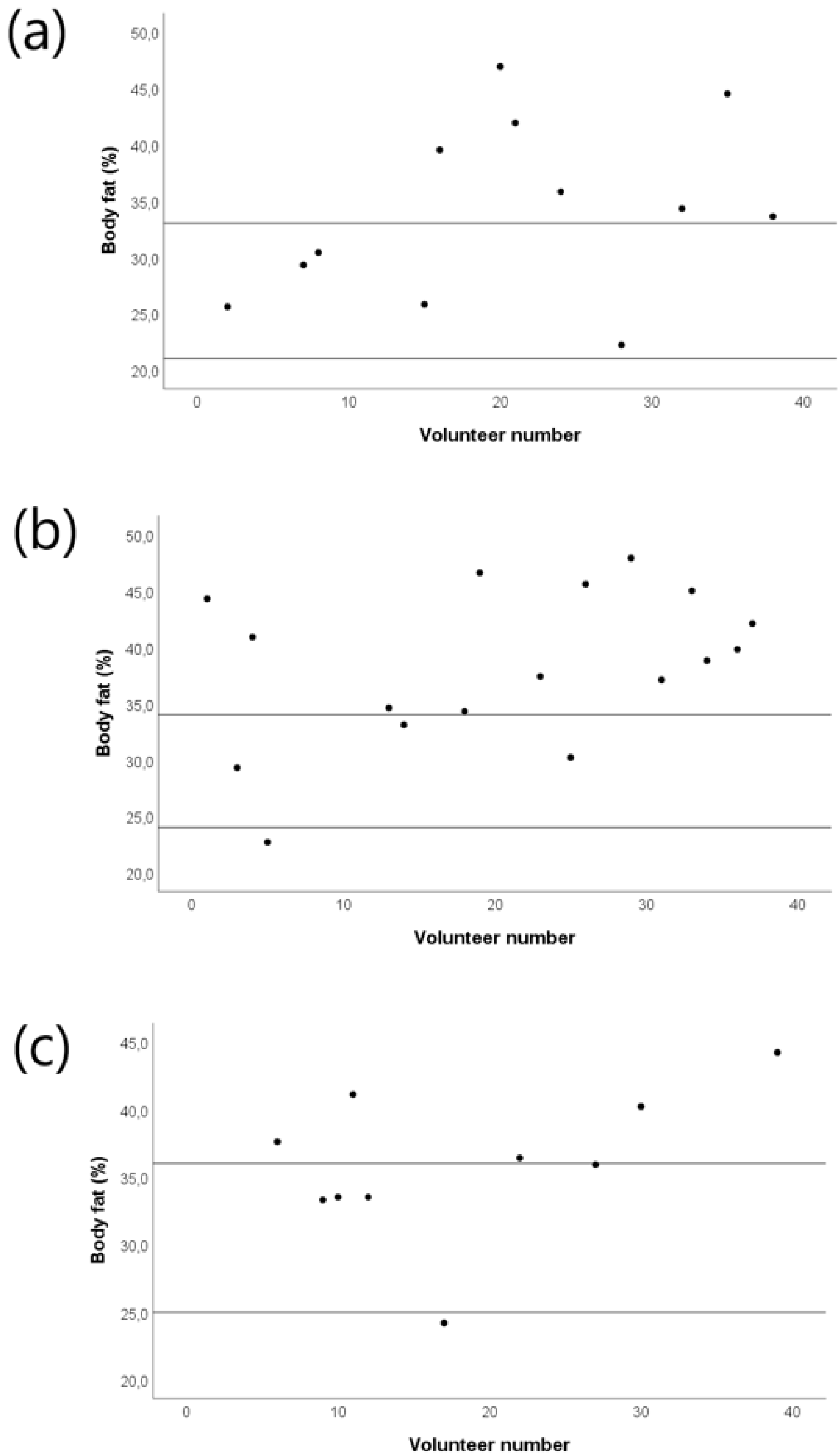

Figure 4

Body composition analysis. (a) body fat in the age group 20-39 years, (b) body fat in the age group 40-59 years, and (c) body fat in the age group 60-79 years.

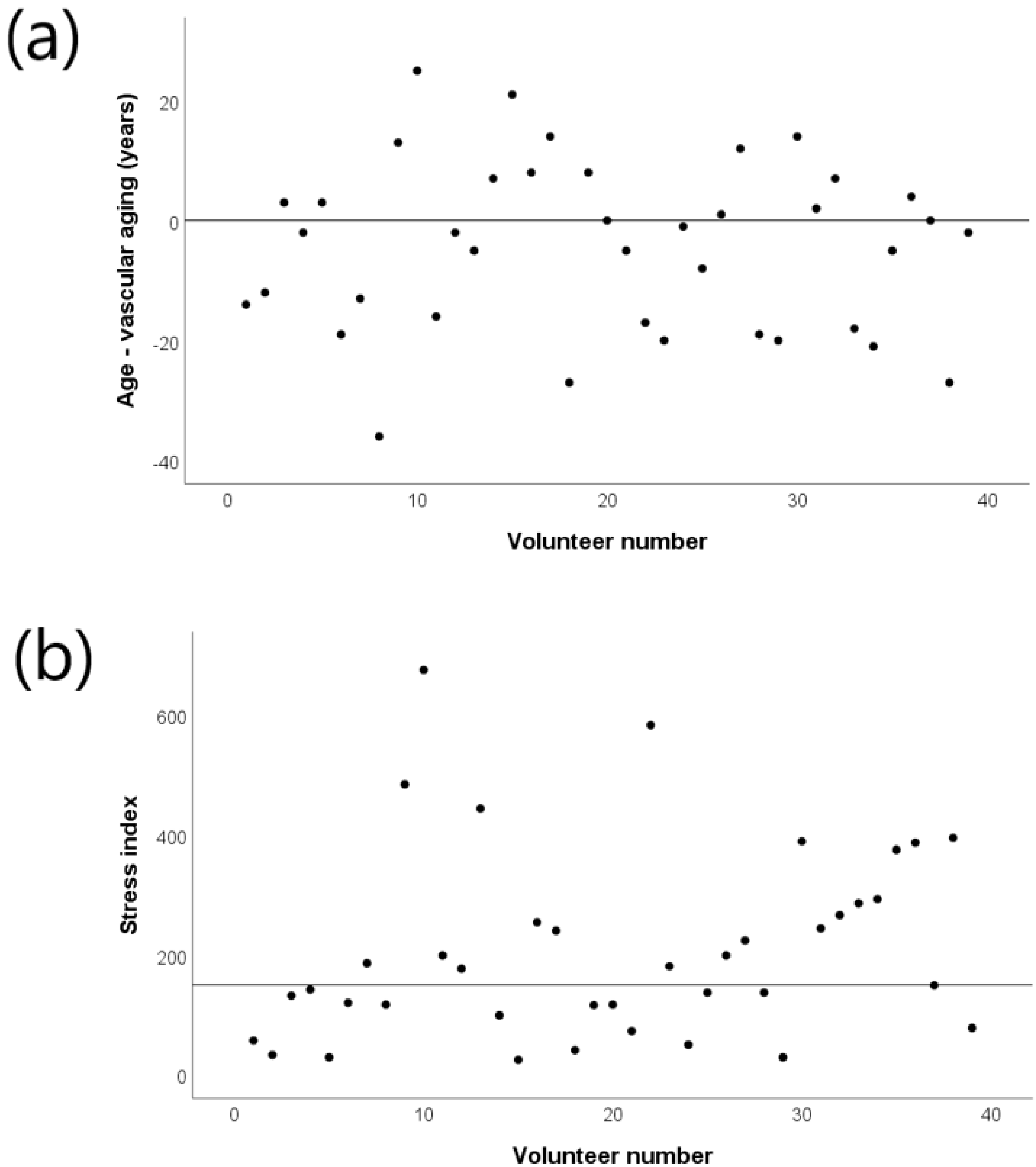

Figure 5

Vascular system analysis(a) difference in real age and vascular aging, and (b) stress index.

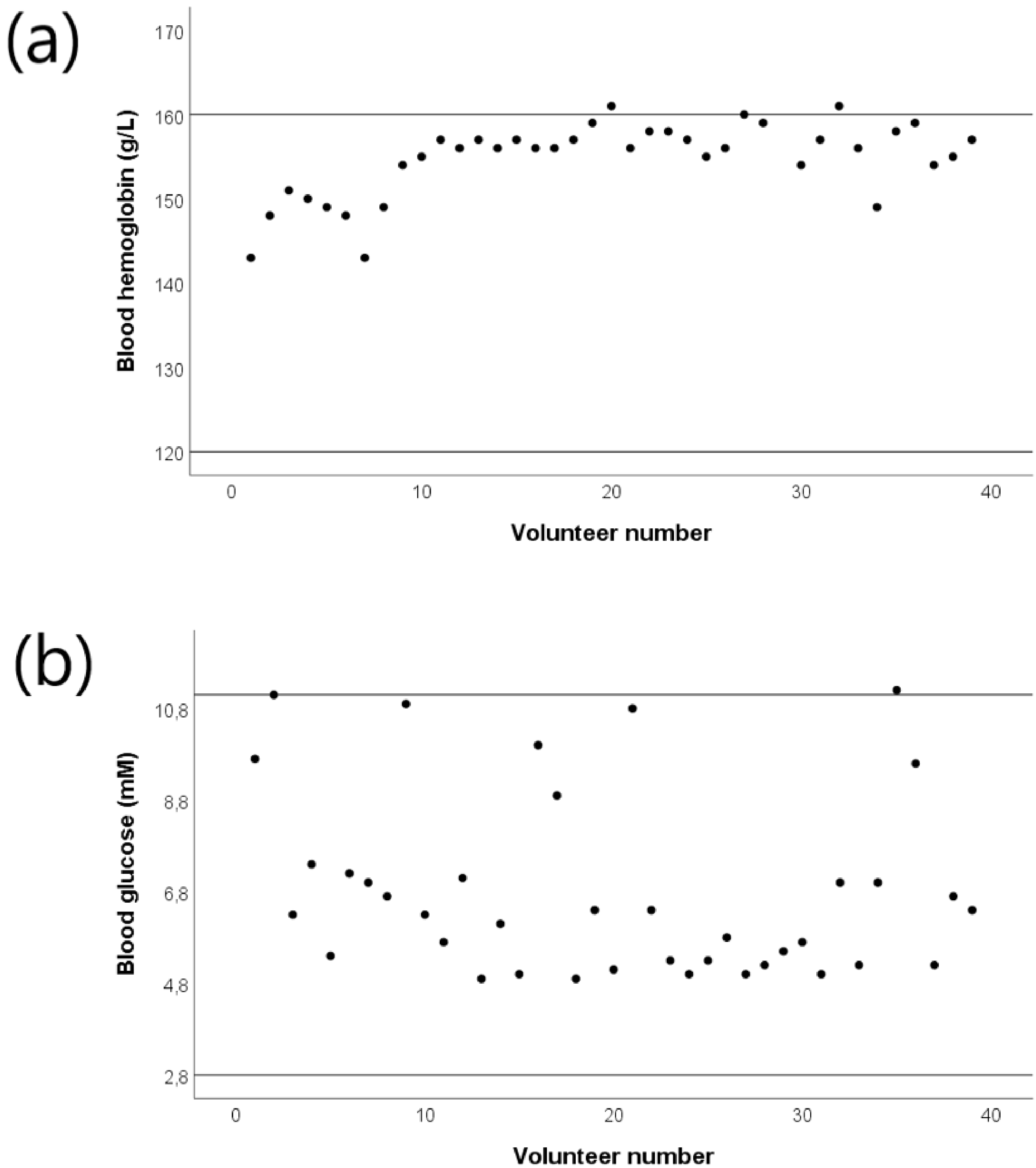

Figure 6

Non-invasive determination of blood bioanalytes. (a) blood hemoglobin, (b) blood glucose.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryInformation.docx