Body-Area Sensing in Maternity Care: Evaluation of Commercial Wristbands for Pre-birth Stress Management

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Abstract. Many women use digital tools during pregnancy and birth. There are many existing mobile applications to measure quantity and length of contractions during early labour, but there is a need to offer evidence-based, credible electronic and digital solutions to parents-to-be. This article presents ongoing research work in a research project regarding mobile telemetric supported maternity care. It summarizes an approach for stress management in late maternity and under birth preparation that is based on body area sensing, our investigation of the properties of commercially available wearable wristbands for body sensing, and the insights gained from testing the wristbands from the project's perspective. We found that sensing precision is very variable depending on the wristband model, while the flows of medical personal data exclusively are routed through vendor cloud platforms outside the EU. The impact of our findings for the use of commercial wristbands in European medical research and practice is discussed in the conclusion.

Keywords: Midwifery · Stress management · Body area networking · Mobile health · Wearables · Self-metering

1 Introduction

The process of childbearing and giving birth is complex, both physically and psychologically. The part of early labour called latent phase is often associated with painful contractions and perceived as a part of childbirth where women experience insecurity, stress and a feeling of being left out from professional care (Ängeby et al. 2018). Women admitted to obstetrical wards during early labour are often subjected to medical interventions (Mikolajczyk et al. 2016), neonatal resuscitation and extended maternal hospital stay (Miller et al. 2020). It is common that women in the latent phase visits obstetrical ward only to be sent home to await a more established labour. Women in labour often

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experience this as stressful and as a rejection from health care (Eri et al. 2015). Health care staff also experience stress when meeting women's needs in early labour (Eri et al. 2011). The wish for a positive birth experience is clearly prominent in literature (Downe et al. 2018) and in 2018, the World Health Organization issued a guideline raising positive birth experience as critical aspect during intra-partum care of high quality (WHO 2018).

2 Stress Reduction Project Vision

During the 20th century, women's birthplace moved from homes to hospital, and women's support from family during all phases of labor ceased. The emotional health and wellbeing of women during childbirth is equally of worth as the medical objectives according to the World Health Organization (WHO). Swedish maternity healthcare has focused on a positive birth experience as an important outcome (SALAR 2016). Women and their partners often feel stressed and omitted in early labor. They demand more support in the form of knowledge and strategies for pain management. The amount of information is extensive but the massive range of information makes it difficult to screen for the women. The amount of mobile applications to measure quantity and length of contractions during early labour is extensive, but with a main focus only in counting time in, and frequency of, contractions (Lupton and Pedersen 2016). The Give Birth Without Fear method was developed by physiotherapists and midwifes with the aim to offer women tools to give birth with confidence. Through a salutogenetic perspective, the method helps the woman to use her own body and mind to reduce stress and fear which inhibits the release of hormones important for labour. The four tools in the method; Breathing, Relaxation, the Voice and the Power of the Mind rests on knowledge of physiology and the importance of support during labour and enables the body's relaxation and release of the peace and calm hormone oxytocin. The Give Birth Without Fear method have been used by tens of thousands of women and it is also applied internationally in healthcare with the nursing model Confident Birth aiming to reduce stress and fear (Heli 2013). The Give Birth Without Fear method was further developed in a process where technicians, women, and their partners participated. From this work, the application called Contraction Coper was developed. The need of digital services for becoming parents got even more evident during the covid-19 pandemic since all parental education were canceled in Swedish primary health care and this further underlines the need of scientific evaluation of the Contraction Coper. A forthcoming project will examine the effect of Contraction Coper application on pregnant women's perceived concerns and stress during pregnancy and birth in a randomized controlled study. Subgroup analyses will be performed using wristband to measure heartrate, sleep, and activity as a proxy for discomfort since pain during contractions causes increase of pulse, sleep-arousal and change of bodily activities. Women and partners use digital tools to keep their bodily changes and the baby during pregnancy. The number of applications, wearable technology, and the uncertainty in scientific underpinning among many of them calls for mobile applications with scientific development and evaluation. As a feasibility study of the effects of wearable technology on stress during pregnancy, early labour and childbirth, the aim was to evaluate six wristbands regarding specifications, functionality, digital privacy, and integrity as well as technical implementation.

3 Technological View on Body Sensing with Wristbands

Our prototype will build a Body-Area-Network (BAN) with remote connectivity and with user interaction. illustrates the technological components. A BAN of one or more sensors connected through a smartphone serving as a data hub will provide the sensing and feedback unit for the pregnant woman (Fig. 1). The hub collects and stores sensor data and captures data steams for stress indicators and activities that will get analyzed. The data then is transferred to the research database. The user may receive feedback and suggestions for stress-reducing activities if healthcare providers offer interactive feedback. Statistics over stress indicators, collected from body sensing, can be presented to the user, together with suggestions for interactive stress reduction exercises.

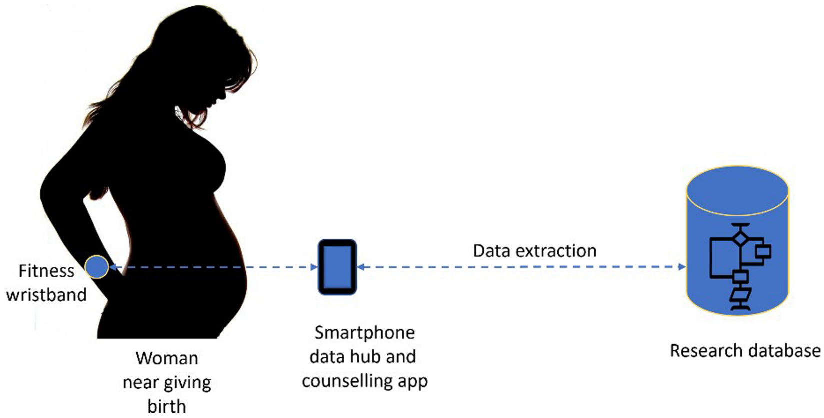

Fig. 1. Body-area network (BAN) and IoT network for envisioned relaxation application.

3.1 Data Architecture

Since the goal of the project is research and development of effective stress-reduction measures, the data collection architecture is likely to get implemented in hybrid ways: Collection and feedback can partially get performed on the smartphone device that serves as the data hub. On the other hand, the health researcher will need access to a more in-depth picture of the patient's stress signals, as well as the captured control data over actual stress-reducing exercise efforts. Medical researchers involved in development may perform additional analysis of the generated data. Due to the data being medical personal data, its handling will need a solid privacy design, de-personalization routines and sufficient levels of secrecy deployed to data storages. Types of data captured from the users are:

- **Personal data processed** from **health system:** Patient identification; relevant medical data from patient journals, relevant background on pregnancy
- **Personal data collected from user and user sensors:** Location through GPS and location services; Movement through accelerometer sensors; Pulse rates (through

pulse sensing); Other sensor readings from wearables (potentially skin conductivity, temperature, humidity, EEG); Direct information collected from GUI with user interaction (surveys on well-being, stress, etc.)

- **Personal data derived from data using the above measurements or health APIs from sensor and wearable vendors:** Calories used during exercise; Quality of sleep metrics; Quantification metrics for activity, such as step counting and others; Psychometrics based on survey responses.

3.2 Other Requirements for Wearables

Wearables used by pregnant women need to fulfil requirements to be considered reliable and safe enough. Parameters of interest are: Reliability and precision of sensing and activity tracking functionality under different activities; Battery lifetime and charging cycle for each wearable; Comfort as well as feasibility of wearing; including adjustable straps or mounting; including waterproofness of wearables; Potential release of unhealthy substances from materials used to build devices; Usability of device, of its user interface, of charging procedure by human under stress.

3.3 Considerations in the Area of Software Engineering

For production, deployment and maintenance of the planned mobile wearable application, a number of requirements from the software engineering perspective will be necessary to consider: The wearables provide sufficient interfaces or APIs for data access and data extraction as well as developer support; Derived data as well as raw data is accessible, either directly from the device or through sufficiently rich cloud APIs; Information security and information privacy are sufficient for handling personal medical information. In summary, the BAN must fulfil requirements towards data quality, reliability, usability, safety, information security, information and data privacy, as well as technical and integration aspects in order to be considered in the project.

4 Evaluation of Commercial Wristbands

For a research prototype, a body-area network composed of commercial pulse measurement wristbands connected to a smartphone is targeted. For this purpose, seven commercially available wristbands were chosen for evaluation: Huawei band 4, Garmin Vivosport, Garmin Vivofit 4, Garmin Vivosmart 4, Samsung Galaxy Fit E, Xiaomi smartband 5, Fitbit companion. The Fitbit device did not arrive and was therefore excluded. Evaluation focused on: Accessible data from measurements, ease of technical integration, data flows, data protection, data sharing. Precision and battery features were assessed. The device evaluation was done in a student project in fall 2020 at Karlstad University (Zaman et al. 2021) that was supervised by the authors.

4.1 Technical Qualities, Sensors and Reliability

The technical features and precision of data delivered was evaluated. Activities were carried out with the wristbands to assess data quality. The bands were equipped with a variety of sensors, as shown in Table 1. Pulse sensor and accelerometer are present in all bands. Derived data is generated in the vendor's supporting cloud services. The portfolio of derived data is diverse. Data includes pace, elevation, calories used, stroke recognition, route tracking, weight tracking and fat-burning counter.

Table 1. Available sensors

	Huawei Band 4	Xiaomi Mi 5	Samsung Galaxy Fit E	Garmin Vi-vosmart 4	Garmin Vi-vosport	Garmin Vivofit 4
Pulse	Yes	Yes	Yes	Yes	Yes	No
GPS	No	No	No	No	Yes	No
Blood oxygen	Yes	No	No	No	Yes	No
Accelerometer	Yes	Yes	Yes	Yes	Yes	Yes
Barometer	No	Yes	No	Yes	Yes	No
Gyroscope	Yes	Yes	No	No	No	No

Pulse measurements were controlled with manual pulse counting with stop watches after a period of activity. The test group found error margins for pulse for Garmin Vivosmart 4 when the person was moving quick. Up to 25% error for the Huawei band were noticed. On average, a deviation of 10–20% between manual pulse rate and wristband pulse rates was observed. Most bands count too high, while Samsung's Fit E counted a few percent too low. Bands were worn on left and right arms respectively. They seemed to work on both arms equally with their respective error margins. For detailed tables with experimental data, see (Zaman et al. 2021).

Accelerometer-based step counting has its pitfalls, too. While all bands get the overall number of steps walked counted with a small error margin, their estimation of the distance walked is unreliable. Only Garmin Vivosport had built-in GPS, providing better total distance walked.

Battery lifetime varied considerably. Table 2 shows the battery life times. The longest time was 7 days. Charging periods were 1−2 h. Garmin's Vivofit 4 has a build-in non-chargeable battery with a projected lifetime of one year.

Sleep quality measurements were carried out by wearing several wristbands at the same time, while keeping notes of sleep interruptions and sleep/wakeup time in a log, which then was compared to the wristband's reports. A rating scale from 1 to 5 was used to judge precision, as well as how informative the sleep quality report was. The result is shown in Table 3. Capture of wake/sleep states was of varied precision. The sleep quality reports were perceived as partially useful.

Table 2. Battery lifetime of wristbands (charging time in hours in brackets)

Huawei Band 4	Garmin Vivosport	Garmin Vivosmart 4	Garmin Vivofit 4	Samsung Fit E	Xiaomi Mi5
7 (2)	4 (2)	6 (2)	365 (–)	4 (2)	5 (2)

Table 3. Result of assessment of sleep monitoring, scale 1–5. Best score: 5.

Type	Xiaomi Mi 5	GarminVivosoft 4	Samsung Galaxy Fit E	GarminVivosport	Huawei Band 4	GarminVivosmart
Accuracy	4.5	2.5	3	5	4	3.5
Informativity	4	1	3	4	5	4

Other Assessments. Waterproofness was one precondition for wearables. All wristbands were exposed to everyday situations exposing them to water (shower, dish washing). All function correct, however touch screens did not work correctly until completely dry. The impact of liquids on the quality of pulse measurements was not assessed. Comfort of wearing versus reliability of measurements was only inspected superficially, since for most bands a certain way of wearing must be considered for their functioning.

4.2 Ease of Integration

Wristband vendors provide proprietary APIs for integration. All except Xiaomi provided development partner programs that govern and regulate access to APIs. Huawei did not answer to access requests in both Sweden and Norway. Samsung provides access through its health API. Garmin provided educational access. Garmin's architecture enables callback access through a server callback URL. Huawei facilitates access through the Health Kit API. Samsung lists a health SDK that provides registered partners access to Samsung's Health Data Store at the Samsung Health Cloud. Conditions for API access are different for each vendor. Their expectation is a signed developer contract with non-disclosure agreement to access the cloud APIs. Data extraction is done through cloud APIs, not directly from the bands. Garmin and Huawei's architectures expect callback URLs in order to deliver data through HTTP requests to a custom application server. The APIs are based on established web technologies. Their technical integration, at least for the two aforementioned vendors, should not pose problems. The detailed functioning of the Samsung API could not get evaluated.

4.3 Data Protection and Data Sharing

Mapping the data flows of sensitive medical personal data was one of the goals of our evaluation. The privacy policies were inspected. The findings were that Samsung, Huawei and Garmin all address European regulation and GDPR compliance in their policies, however to varying degrees. Xiaomi defines the location of legal disputes as China, even though they reference GDPR as compliance framework for personal data. Privacy policies are written for various mobile products, not specifically for the wristbands. They hardly define storage location or storage period of the collected data. Various channels for data subject intervention are mentioned, often as e-mail addresses. Personal data is indexed by wristband device ID, by smartphone identity data (which can deliver many identity attributes, see (Momen and Fritsch 2020)), and through accounts on vendor cloud platforms. Platforms provide interfaces to fitness monitoring social media platforms, which can cross-reference tracking data. Overall, from a medical privacy perspective, it will be a demanding task to secure wristband tracking data on its way through the platform ecosystem of the respective vendor that is distributed onto servers outside the domain of Europe's GDPR, as sensitive medical data is seldom permitted stored outside the EU by local regulators. Alternative strategies, such as the registration of pseudonymous user profiles and accounts must be considered, as well as the sanitization person-relatable data, such as GPS location. Regarding information security, the products only provide very basic security. Transmission security with SSL/TLS, API software tokens and password authentication are the technologies used. No multi-factor authentication, no end-user cryptography, no data authentication or integrity protection beyond transport security was visible in the documentation. The wristband products do not seem to have been developed with a medical privacy context in mind. Our findings are consistent with a detailed report by Canadian privacy researchers (Hilts et al. 2016).

5 Conclusion

Our evaluation of commercial wristbands arrives at several important conclusions. First, the precision of sensor measurements has a considerable error margin, which must get evaluated for its implications for the stress management supervision context. While wristbands were powered over several days, and generally robust and waterproof, their quality of derived data such as sleep quality had a wide spectrum of precision.

Data access is provided through the vendors' respective cloud platforms. Data cannot directly get accessed from the wearables. Therefore, vendor apps must get installed on smartphones, which then push the apps to the vendor tracking cloud platform. There, derived data is generated, and APIs provide access to apps and fitness tracking platforms. We did not notice any specific functionality for the management of medical privacy. Software development support was available for most vendors. Garmin's equipment was most accessible for software development. Generally, vendors were looking for large-scale partners rather than development projects or experimental access to their software platforms. The platforms appear being planned for a larger ecosystem of consumer devices getting developed around them. Functionality envisions data sharing with fitness tracking social media platforms. A more thorough analysis of the privacy consequences of such architectural features must be done before experimenting with medical data. A negative finding was the cloud-based data access options for all evaluated wristbands. This causes major data protection issues, as personal data, and potentially sensitive medical data, is exported to 3rd-country cloud storage. Therefore, the body-area network architecture would either need audited data processor agreements, or cloud servers hosted in Europe. None of the commercial wristbands offered this option in their documentation. We need therefore resume our search for wearables that are both matured consumer-safe products and offer direct access to the data.

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References

Ängeby, K., Sandin-Bojö, A.-K., Persenius, M., Wilde-Larsson, B.: Early labour experience questionnaire: psychometric testing and women's experiences in a Swedish setting. Midwifery **64**, 77–84 (2018)

Mikolajczyk, R.T., Zhang, J., Grewal, J., Chan, L.C., Petersen, A., Gross, M.M.: Early versus late admission to labor affects labor progression and risk of cesarean section in nulliparous women. Front. Med. **3**, 26 (2016). https://doi.org/10.3389/fmed.2016.00026

Miller, Y., Armanasco, A., McCosker, L., Thompson, R.: Variations in outcomes for women admitted to hospital in early versus active labour: an observational study. BMC Preg n. Childbirth **20,** 469 (2020). https://doi.org/10.1186/s12884-020-03149-7

Eri, T.S., Bondas, T., Gross, M.M., Janssen, P.A., Green, J.M.: A balancing act in an unknown territory: a metasynthesis of first-time mothers′ experiences in early labour. Midwifery **31**(3), e58–e67 (2015). https://doi.org/10.1016/j.midw.2014.11.007

Eri, T.S., Blystad, A., Gjengedal, E., Blaaka, G.: 'Stay home for as long as possible': Midwives' priorities and strategies in communicating with first-time mothers in early labour. Midwifery **27**(6), e286–e292 (2011)

Downe, S., Finlayson, K., Oladapo, O., Bonet, M., Gülmezoglu, A.M.: What matters to women during childbirth: a systematic qualitative review. PLoS ONE **13**(4), 1–17 (2018)

WHO recommendations: intrapartum care for a positive childbirth experience. Geneva: World Health Organization: Licence: CC BY-NC-SA 3.0 IGO (2018)

Sveriges Kommuner och Regioner (SALAR): Förlossningsvård och kvinnors hälsa i fokus. E. Estling. Sveriges Kommuner och Landsting, Stockholm (2016)

Lupton, D., Pedersen, S.: An Australian survey of women's use of pregnancy and parenting apps. Women Birth **29**(4), 368–375 (2016)

Heli, S.: Confident Birth: Pinter & Martin Publishers, London (2013)

Zaman, S., Tunc, E., Bahmiary, D.: Wristband evaluation. techical report, 55 pages, Karlstad University, Faculty of Health, Science and Technology, Sweden (2021). http://urn.kb.se/resolve?urn=urn:nbn:se:kau:diva-83399

Momen, N., Fritsch, L.: App-generated digital identities extracted through an droid permission-based data access a survey of app privacy. In: Reinhardt, D., Langweg, H., Witt, B.C., Fischer, M. (Hrsg.) SICHERHEIT 2020, pp. 15–28. Gesellschaft für Informatik e.V., Bonn (2020). https://doi.org/10.18420/sicherheit2020_01

Hilts, A., Parsons, C., Knockel, J.: Every Step You Fake: A Comparative Anal ysis of Fitness Tracker Privacy and Security. Open Effect Report (2016). https://openeffect.ca/reports/Every_Step_You_Fake.pdf