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Wearables and Apps – Modern Diagnostic Frameworks for Health Promotion through Sport

Wearables und Apps als moderne diagnostische Frameworks zur Gesundheitsförderung durch Sport

REVIEW

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Summary

- **Modern technologies** like wearables and fitness apps are experiencing increasing popularity in assisting daily life activities. Based on the yearly socio-economic potential of up to 100 billion euros within the European Union, these technologies are becoming increasingly interesting for scientists and physicians. In 2015 there were more than 100.000 health-related apps. As a result of the continuously rising number, it is hard to stay up to date. Additionally, the enormous and steadily growing number of wearables in different fields of application (commercial, scientific, experimental) makes it impossible to keep an overview.
- **Therefore, a critical** review of current tendencies and developments has been performed. Depending on the target audience, the intricacy of such technologies reaches from simple step recognition for estimating physical activity in daily life to complex detection of disease-related events for medical diagnosis. Digital patient diaries, nutrition databases with more than two million integrated dishes as well as cardio-vascular monitoring devices are promising fields of application.
- **Validity of the methods** used and of the physical activity estimation has been shown by comparison to gold standard methods and clinical trials in many cases. Technical requirements, data security and missing implementation of behavior-changing elements can be seen as current risk factors of mobile health applications and therefore constitute the basis for better exploitation of the potential of these technologies.

Zusammenfassung

- **Moderne Technologien** zur Begleitung alltäglicher Aktivitäten wie beispielsweise Wearables oder Fitness Apps erfreuen sich zunehmender Popularität. Auf Grund des enormen sozio-ökonomischen Potentials dieser Technologien in Höhe von jährlich rund 100 Milliarden Euro innerhalb der Europäischen Union wird zunehmend das Interesse der Bereiche Wissenschaft und Medizin geweckt. Da im Jahr 2015 bereits über 100 000 gesundheitsrelevante Apps existieren und diese Anzahl stetig steigt, muss massiver Aufwand betrieben werden, um auf dem Stand der Technik zu bleiben. Zusätzlich macht es eine enorme, stetig wachsende Anzahl von Wearables in den verschiedensten Anwendungsbereichen (gewerblich, wissenschaftlich, experimentell) fast unmöglich, einen Überblick über diese Technologien zu behalten.
- **Daher kann es als sinnvoll erachtet werden,** aktuelle Tendenzen und Entwicklungen kritisch zu beleuchten. In Abhängigkeit vom Zielpublikum reicht die Komplexität der Anwendungsgebiete von einfachen Schrittzählern zur Ermittlung der täglichen physischen Aktivität bis hin zur Erkennung krankheitsinduzierter Ereignisse für medizinische Diagnosezwecke. Digitale Patiententagebücher, Nahrungsmitteldatenbanken mit mehr als 2 Millionen implementierten Speisen sowie kardiovaskuläre Aufzeichnungsgeräte zählen zu vielversprechenden Anwendungen.
- **Die Validität der verwendeten Methoden** sowie der Aktivitätsbestimmung konnte in vielen Fällen durch den Vergleich mit Goldstandard-Methoden und klinischen Studien bestätigt werden. Technische Erfordernisse, Datensicherheit und fehlende Einbindung von verhaltensverändernden Elementen zählen derzeit noch zu den Risikofaktoren und Schwächen solcher Anwendungen und bilden somit den Ausgangspunkt für eine bessere Ausschöpfung der Potentiale dieser Technologien.

KEY WORDS:
Wearables, Apps, Diagnostics, Health, Sport

SCHLÜSSELWÖRTER:
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Introduction

Computerization, digitalization and growing connectivity are changing our life in many different ways. Technical devices become smaller, more efficient and are connectable to other devices. Even though for medical and preventive applications this progress is still in its infancy, two novel technologies called "wearables" and "apps" induce several changes in these fields and further help to prevent diseases (1).

In this summary we provide basic information regarding measuring principles, give an overview of the areas of application and discuss the potential benefits, risks and barriers of such technologies.

Table 1

Degree of measuring technology implementation for wearable devices (+ frequently; o occasionally; – rarely).

TECHNOLOGY/DEVICE	PARAMETERS	COMMERCIAL	ADVANCED	EXPERIMENTAL
Accelerometer	Physical Activity, Steps, Distance, Orientation	+	+	–
GPS Signal	Distance	+	+	–
Skin Electrodes	ECG, EMG, EEG, HRV	o	+	o
Pulse Oximeter	Oxygen Saturation	–	+	–
Electrical Resistance	Force, Skin Temperature, Breathing Frequency, Salivary Uric Acid	–	o	+
Visual Systems	Eye Movements, Blinking Rates, Mental Fatigue	–	o	+

Wearables

Wearable technologies are the most important fitness trend in 2016 and thus outperformed previous trends like body weight training or high-intensity interval training (28). These computer-based technologies are worn on the human body and characterized by wireless connection technologies and a high degree of miniaturization. They can be used for collecting and analyzing health-related data (e.g. walking distances, steps, heart rate, skin temperature) and provide the possibility to diagnose or monitor several kinds of diseases like Parkinson's Disease (18) or Cerebral Palsy (13) over a long period of time without any additional input. Typical examples are intelligent wristbands, smartphones, smartwatches or "smarttextiles".

Generally, there are three types of wearables: the "common" or "commercial" ones available for the general public (e.g. Nike Fuel Band, Fit Bit, MisfitShine, RuntasticOrbit), the "advanced" or "high quality" ones mostly used in scientific fields (e.g. Axivity, ActiGraph, TriTracR3D, The Caltrac) and the experimental ones typically being in the development stadium. While most of the commercial wearables focus on measuring and analyzing physical activity, travel distances and steps, the two other groups utilise a broader spectrum of measuring devices (see Table 1). In addition, differences in raw data access possibility, resolution of data (5), implemented algorithms, validity (9) and price can be found. Due to limited raw data availability for many commercial wearables, the implementation of these devices for medical or scientific applications is rendered difficult. Contrary to official recommendations to provide raw values (e.g. acceleration or ECG data) (31), they enable access to smoothed and summarised information only (e.g. steps per day or average pulse rate). Furthermore, built-in sensors in smartphones do not achieve sufficient time resolution for medical applications.

Fields of Application

Given the simplicity and small size of wearables, they are used in diverse fields of application. Mostly, they can be found in sports or daily life activities, medicine, prevention and rehabilitation.

In sports or daily life activities, wearables are most frequently used for tracking daily physical activity (26) as well as vital parameters (7). Especially for occupational environments, additional efforts have been made in detecting stress periods (22) or mental fatigue states (30). Other fields of application such as grip posture recognition in golf, tackle recognition in rugby or repetition tracking during weight lifting, can rather be classified as individual applications.

In medicine or prevention, wearables are generally applied in a more sophisticated way. In addition to collecting physical activity data, they can be used to promote physical activity (6) and record vital parameters or digital patient diaries (e.g. food, physical and mental state, health-related events). Moreover, it has successfully been shown that in case of diseases like Tourette syndrome (4), Parkinson's disease (18), Cerebral Palsy (13) or Multiple sclerosis (8) for which the detection of disease related events (e.g. ticks, freeze of gait, spasms) is required, wearables can help to complement regular pen and paper patient diaries.

In rehabilitation, the main use of wearables is real time detection of vital parameters (see Figure 1). Smartphones can be used to send vital parameters to clinicians or family members (23) and in case of emergency, automated operations can be initiated to provide immediate support to patients. GPS signals can be used to locate missing people (e.g. for people with dementia) and acceleration data can be utilised to figure out movement or sleeping habits (e.g. toilet visit). Sleeping quality assessments can offer rough estimates about sleeping habits (e.g. time in bed) but cannot be used to replace polysomnography in laboratory conditions.

Data Validity

Data validity is a prerequisite for accurate diagnosis or feedback. Due to the nature of validity studies (expensive, complex, time consuming), most of them can be found in research projects only. Although validation processes have been undertaken for high-quality wearables, a standardization of data collection, processing and analytical procedures is still required to guarantee data comparison (31).

Most of the available wearables are designed for specific application positions. Only when attached at the appropriate location, high data reliability may occur. However, their accuracy can decrease due to misplacement (12). Especially for wearables based on acceleration data, there are some systemic risks for estimating physical activity. As their estimation of physical activity is based on counting impacts or steps per minute (with a database in the background), movements causing fewer impacts (e.g. cycling) or more impacts (e.g. dish washing) near the sensor position (e.g. wrist) can lead to underestimation or overestimation of physical activity, respectively. In general, an underestimation of daily life activity, proven by gold methods (e.g. indirect calorimetry or doubly-labeled water) has been found (25). To reduce this estimating errors, additional pre-existing technologies (e.g. GPS, ECG), which are featured by high reliability, can be used. It had been shown, that the additional usage of ECG signals paired with pattern recognition algorithms can detect misclassifications and therefore help to estimate the physical activity more accurately (5). Additional subjective data collection (e.g. questionnaires for feelings or emotions) can be used to describe users´ physical and mental states in a more appropriate way (26). Due to its cumbersome integration (e.g. data entry on the device) and fears that additional measuring technologies or devices may also reduce acceptance rates (9), subjective data collection is rarely implemented.

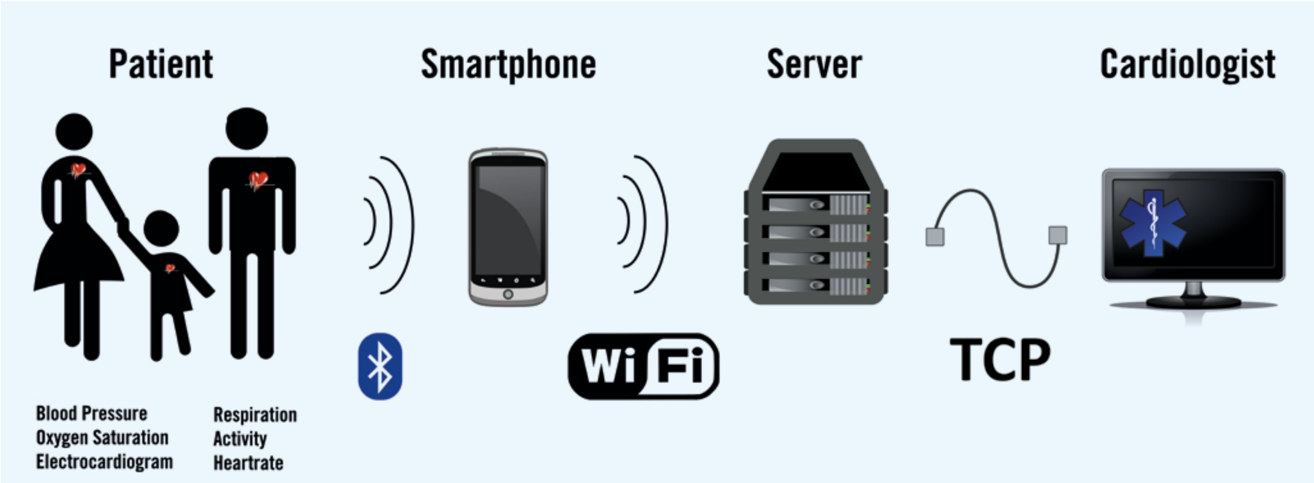

Figure 1

Real-time transmission of vital parameters by means of wearable technology (schematic overview).

Risks/Barriers

Continuous measurement of sensitive data (e.g. blood pressure) is a double-edged sword. It can help to improve the accuracy of a diagnosis, but can also trigger general concerns about data and application security (8). Personal data is often stored in digital clouds, where a transfer to a third party cannot be fully excluded. Additionally, 'good' values shown by the wearable (e.g. blood pressure, heart rate) can deliver wrong impressions of the users' physical states and lead to undesirable effects (e.g. medication stop). To minimize this problem, the usage of wearables for medical and rehabilitation applications should always be accompanied by a trained and experienced physician.

Nearly one third of all US-American wearable users stopped using their gadget within six months (8). It can be figured, that this might partly be caused by the absence of feedback, visualisations or other behaviour change elements. Wearables with feedback can promote significant increase in physical activity, while those without any feedback do not (6). Clunky, heavy or remarkable design as well as technical aspects, such as water resistance, usability or maintenance intervals, are further challenging factors with possible influence on usability (27). Especially in case of people who are not used to electronic devices (e.g. elderly), minor problems (e.g. an empty battery) or misleading navigation can stop the willingness to use novel technologies and impede corresponding diagnosis.

One possibility to reduce the risks and barriers of wearables is the implementation of mobile fitness apps. Outsourcing visual components (e.g. removing the display) helps to reduce the size of wearables and therefore encourages small, light and comfortable devices. Moreover, the simplified possibility to implement behaviour change elements (e.g. feedback) can positively influence acceptance rates.

Mobile Apps

Application software ("apps") are computer programs designed for executing predefined functions. Due to the growing spread of smartphones, mobile offshoots ("mobile apps") enjoy a continuous increase in popularity and fitness apps are forecasted to be ranked among the top 20 fitness trends in 2016 (28). Mobile apps enable smartphones to be used as mobile computer stations and further open the door for any thinkable usage (e.g. mobile health applications). Up to now, nearly 20 percent of all smartphone users have downloaded a health-related app (10), that allows them to determine and reproduce health-related parameters (e.g. walking distance, heart rate). According to forecasts, the coverage of mobile health apps will have reached 33 percent by the end of 2015 (19). This enormous popularity can also be found in the software development field. In 2010 within six months the number of available health-related apps in the Google-Play and ITunes stores has increased by 66.6% and 156.6%, respectively (14).

Fields of Application

In 2015 existed more than 100.000 health-related mobile apps (11, 21). Nearly 60% of them deal with promotion of weight loss and physical activity (3). "Weight-loss-apps" are mainly based on nutrition databases. Some of them (e.g. "MyFitnessPal") exhibit more than two million different types of food and thereby help their users to estimate their food intake. Especially for overweight and obese people, who often suffer from wrong self-estimation (16), this kind of app can be helpful in regard to regulation of their bodyweight. People facing a diet achieved higher success rates (more physical activity, higher weight loss), when using a mobile health app instead of a traditional pen and paper diary (29). Similar success rates have been found for smoking cessation. By means of mobile apps the chance of being abstinent increased from 4-5 percent to up to 6-10 percent (24).

For physical activity approaches, mobile apps are mainly designed for collecting, analysing and visualising physical activity data provided by smartphones or additional wearables. They provide information regarding steps covered, daily physical activity as well as resulting energy consumption (mainly based on the Compendium of Physical Activity (2)) and make it possible to share this information with the community. Additional behaviour change theory elements (e.g. instructions or feedback) are often implemented in mobile apps to enhance acceptance and performance (20).

Further health-related applications for mobile apps are reminders for medication intake, patient diaries as well as assisting people with disabilities or chronic diseases (14).

According to economical calculations the potential savings generated by using health-related mobile apps in the European Union, less the estimated cost of implementation of this technology, amount to 100 billion Euros per year (24).

Risks/Barriers

One of the main risks for implementing mobile health applications is "app escape". The fact that 80 to 90 percent of health-related mobile apps are uninstalled after first usage (19) shows that there are still some gaps in their development process. While apps follow fancy design and logical structures, generally, they exhibit fewer behavior change or gamification elements. These elements, based on behavior change theory elements, have originally been used in computer games to enhance satisfaction and subsequently ensure the success of the game. Personalized goal setting (lower goals for worse players), targeted feedback (help for difficult tasks) or leaderboards (comparison with others), are only three of twenty-six possible gamification elements (20). Despite the variety, only 52.5% or 28.8% of all fitness apps contain at least one or three gamification elements, respectively (17). The most frequently used elements are social or peer pressure (45.2%), social rewards (24.1%), competition (18.4%), leaderboards (14.2%), level of achievement or rank (13.4%) and real world prices (10%).

Even though sharing personal achievements or other gamification elements can help to increase users´ motivation (15, 17), these elements can facilitate data collection for third parties. Especially for people with diseases, this circumstance can lead to negative consequences (e.g. higher fees for health insurance).

Another potential risk for mobile health apps is the epidemiological user behavior. While most of the app users are young and healthy people, unhealthy and elderly people are inadequately represented (14). Reasons for this are missing inclusion in the app developing phase, mental overload as well as fear to lose supervising therapists, when using the apps (14).

Future Prospect

Currently, physicians can benefit from mobile technologies, if continuous measurements are required for medical diagnoses. They can help to get a better insight into patients' lives as well as their environmental conditions (e.g. food intake, blood pressure) and therefore support a more accurate diagnosis. As a result of their availability, data validity and capability, the usage of mobile technologies for medical fields is still in its infancy. Due to the "Internet of Things", smaller, more efficient and decent mobile devices will enter the market and subsequently enable novel areas of application. As medical and rehabilitation applications require proper data, their growing number will encourage commercial wearable manufacturers to validate their products to guarantee therapeutical improvements. Standardized monitor calibration, data collection, data processing, data analytical procedures as well as international databases (e.g. global repositories of objectively measured activity monitor data) will enable data comparison, help to improve surveillance of physical activity around the world and provide statistically more powerful etiological analyses on dose-response associations with health outcomes (31).

Future devices will promote continuous measurements, will be connected to each other and will facilitate an overview of vital parameters not based on selective measured data only. They will allow physicians to save time and diagnose and administer therapies more efficiently. Especially in areas with a shortage of physicians, these circumstances can further help to ensure medical care. Regardless of their benefits, personal data should be collected, stored and secured under the highest possible standards, to avoid the glass human being and accompanying risks.

Conclusion

It has been shown that a huge number of wearables and health-related apps are currently available on the market. The multitude of different applications makes it nearly impossible to become familiar with all of them. The general benefits of these new technologies have been illustrated. Problems with acceptance rates, validation progresses and data security have to be mentioned and considered. Given the stupendous socio-economic benefits of these technologies, there is a strong presumption that they will increasingly become a common part of our daily life. ■

Conflict of Interest

The authors have no conflict of interest.

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Wearables und Apps als moderne diagnostische Frameworks zur Gesundheitsförderung durch Sport

Wearables and Apps – Modern Diagnostic Frameworks for Health Promotion through Sport

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Einleitung und Fragestellung

Diese Übersichtsarbeit basiert vorwiegend auf sportmedizinisch ausgerichteten Inhalten aktueller (≤3 Jahre), internationaler wissenschaftlicher Journalartikel zu den Themen Wearables und Fitness Apps und liefert grundlegende Informationen zu Messprinzipien, Anwendungsgebieten sowie Potentialen und Risiken solcher Technologien.

Während kommerzielle Wearables und Fitness Apps derzeit nur einen Bruchteil verfügbarer Messsysteme verwenden (vorwiegend um körperliche Aktivität zu bestimmen), ermöglicht der zunehmende Miniaturisierungsgrad von Sensoren immer neuere und spannendere Anwendungsgebiete. So können Wearables nicht nur als einfache Schrittzähler, sondern auch zur Detektion krankheitsbezogener (z. B. Spasmen bei infantiler Zerebralparese) oder sportbezogener (z. B. Tackle-Detektion beim Rugby) Ereignisse verwendet werden. Auch die Übertragung von vitalen Parametern in Echtzeit, digitale Patiententagebücher oder Nahrungsmitteldatenbanken mit mehr als 2 Millionen implementierten Speisen zählen zu den vielversprechenden Anwendungen.

Ergebnisse und Diskussion

Die Verwendung von Fitness Apps ermöglicht es, neben der einfachen visuellen Darstellung von Messwerten, auch bisher schwierig zu implementierende verhaltensverändernde Techniken in den Alltag einzubauen. Diese aus der Verhaltenspsychologie stammenden Techniken erlauben es, gepaart mit in der Spielindustrie vorherrschenden Gamification-Elementen, deutlich höhere Behandlungserfolge bei Therapien zu erzielen.

Wenngleich sich medizinische Diagnosen durch kontinuierliche Messaufzeichnungen präziser und leistungsoptimierter gestalten lassen können, bergen neue Technologien auch Risiken. Viele der derzeit im kommerziellen Bereich erwerbbaren Produkte wurden nicht ausreichend validiert und können daher zu erheblichen Messungenauigkeiten führen. Die daraus resultierenden Fehlinterpretationen, insbesondere bei fehlender Einbindung von medizinischem Personal, können Therapieerfolge massiv gefährden. Auch die permanente Überwachung von vitalen Parametern birgt hohe Sicherheitsrisiken. Ohne geeignete Schutzmechanismen und Regulatoren könnte der Patient zum gläsernen Menschen werden. Eine unkontrollierte Weitergabe persönlicher Daten an Dritte könnte dabei weitreichende Folgen mit sich bringen (z. B. erhöhte Versicherungsprämien).

Fazit für die Praxis

Valide und vernetzte Messmethoden sowie eine erhöhte Prävalenz leistungsstarker Sensorik werden fortlaufend neue und innovative Anwendungsbereiche schaffen. Sie werden es ermöglichen, Diagnosen immer präziser und vor allem individueller stellen zu können. Unter der Voraussetzung geeigneter rechtlicher Rahmenbedingungen sowie sicherheitsrelevanter Vorkehrungen werden diese Technologien einen wesentlichen Beitrag zur zukünftigen Effizienzsteigerung im Gesundheitssystem leisten.

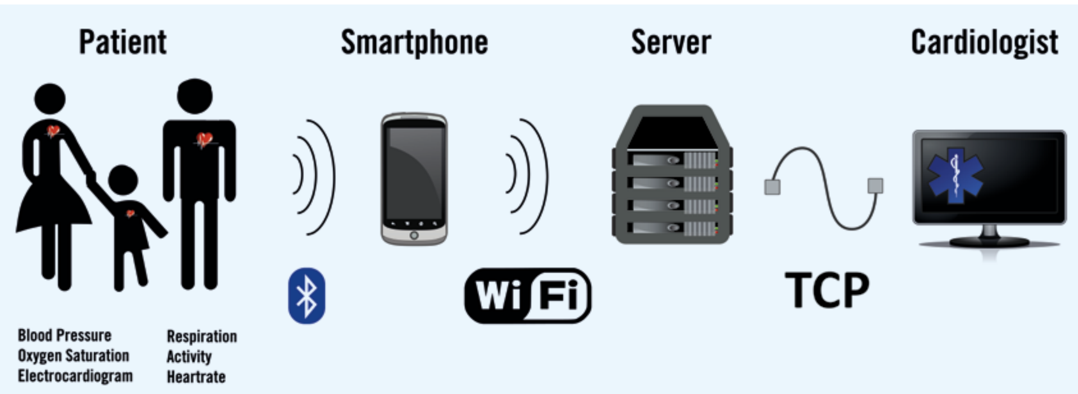

Abbildung 1
Schematische Darstellung einer Echtzeitübertragung von vitalen Parametern des Patienten zum medizinischen Personal.