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The Comparison of Wearable Fitness Devices

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Abstract

The wearable devices or wearable trackers help to motivate you during daily exercise or workouts. It gives you information about your daily routine or fitness by using wearable technology in combination with your smart phone to track your daily activities and fitness without the manual calculations or records that can be intrusive. Generally, companies display advertising for these kinds of products and depict them as good, user-friendly, and accurate. However, there are no subjective research results to prove the veracity of their words. Four popular wrist band-style wearable devices currently in the market were selected at the devices which are most popular (Withings Pulse, Misfit Shine, Jawbone Up24, and Fitbit Flex). The accuracy of tracking was one of the key components for fitness tracking, with some devices performing better than others. Accuracy in the tracking of daily activities such as walking, running, and sleeping is important. This research showed subjective and objective experiment results, which were used to compare the accuracy of four wearable devices in conjunction with user-friendliness. Satisfaction levels, the accuracy of tracking, and the opinion of each subject while using wearable device to track their daily activity were compared. The results determined that the cost-effectiveness was the Withings Pulse, followed by the Fitbit Flex, Jawbone Up24, and Misfit Shine.

Keywords: wearable devices, Withings, Fitbit, misfit, jawbone, best tracker

1. Introduction

There are many online reviews of wearable trackers, typically presenting different perspectives on the rankings. However, objective and factual information cannot match the subjective findings which convey further details about the devices, the participants in the experiments, or the particular reviewers involved. Further, there is no quantitative comparison table to show the results of subjects reviewed. For example, from the site of "Top Ten reviews" [1, 2],

the best wearable device reviewed was the Fitbit Flex, followed by the Withings Pulse, Jawbone, and Misfit. From this site, the table score was shown and compared but provided no details about where the information originated. Another example for a wearable tracker review site is "Best fitness tracker 2015." From Wearable Tech for your connected self [3], the top four trackers were Jawbone, Misfit, Fitbit, and Germinly, respectively. Online reviews rarely present objective and measurable comparison data, and the review content is usually only the opinions of bloggers. While the information is subjective in such cases, it is useful for customers who are considering purchasing a tracker, since the content can guide the customer to find the right product to meet their needs. However, customers would benefit greatly if the information offered included subjective comparison results which could let customers know which trackers would be the best fit for their requirements [4–6].

This research study provides a comparison among the leading wearable fitness-tracking devices available today, covering the accuracy, user-friendliness, and customer satisfaction. All the selected devices were of the wristband type and ranked within the top ten of the best 2015 products from reviews [1–3]. Four of these products were selected randomly: the Fitbit Flex (Fitbit Inc., San Francisco, California, USA) [7], the Withings Pulse (Consumer Electronics, Issy-les-Moulineaux, France) [8], the Misfit Shine (Msfit Inc., Apple Inc., Apple, Mitten Rd., Burlingame, California, USA) [9], and the Jawbone Up24 (Consumer Electronics, San Francisco, California, USA) [10–13]. The results will be shown as subjective and objective research results for the trackers with the best accuracy and user-friendliness by physical information from real users.

This paper reviews the following: (1) the overall specs of four devices were compared, (2) the user satisfaction for all four devices and compares the results of the satisfaction scores, (3) the opinion from user in experiments were explored, (4) the reviews of wearable devices of blogger or reviewer from internet site were compared with linking to the users' opinion in experiments, and (5) the accuracy and repeatability of activity tracking for each model were also recorded and compared.

2. Material and methods

2.1. Wearable devices used in the experiment

The four wearable devices in the experiments were done randomly for wrist band devices available in Korea, chosen from ten devices in the top ten review rank [1–3] (see **Figure 1**). The four devices are Jawbone Up24, Misfit Shine, Fitbit Flex, and Withings Pulse. **Table 1** provides the comparable features of the four wearable devices.

2.2. The user interface application (UI app) of each devices

Most wearable devices differ in their user interface. The UI design for wearable devices should be simple, clear, and quick to navigate for users' comfort [3]. This is not an easy design feature since wearable wrist devices have to be small. As a result, devices which link to a smartphone though a UI app have become more popular among users. The smartphone apps which work

Figure 1. The wearable devices in the experiments: (a) Fitbit flex, (b) Withings pulse, (c) misfit Shine, and (d) jawbone up.

with wearable devices must therefore be easy to download. The app also serves to process the collected data, store the data, and perform network activities [6].

2.3. Experiment methods

2.3.1. Subjects

Seven healthy subjects participated in the experiments, comprised of six healthy men (adults aged 27–50 years, mean age of 31 years old, mean height 171.5 cm, and mean weight 68.18 kg) and one healthy woman (adult aged 30 years, height 160 cm, and weight 42.1 kg).

Each participant wore each of the four devices for 1 week in turn, taking notes throughout of the results of their usage, their satisfaction levels, and their point of view regarding the benefits and shortcomings of each product. Upon completion of the testing cycle, the four devices were all tested in order to confirm the accuracy of the recorded data. The experiment details are outlined in Section 2.3b.

2.3.2. Experimental methods

2.3.2.1. Subjective satisfaction of wearable device users

During the course of this study, each participant wore each of the four wearable devices for 1 week periods, completing the evaluation form to assess their satisfaction levels upon completion of the week. The total test duration was 1 month. The evaluation form had two sections.

Section 1. The Likert scale used to evaluate the devices.

The participants provided scores using the five-point Likert scale for each category on each device, assessing the design, functions, and features after the 1-week test period when the device was worn every day. A score of five indicated a very positive assessment, while one represented the poorest performance. The evaluation form comprised two parts:

Features	Specifications	Jawbone Up24	Fitbit Flex	Withings Pulse	Misfit
Company detail	Company name	Consumer Electronics	Fitbit Inc.	Consumer Electronics	Misfit Inc.
	Country	San Francisco, California, USA	San Francisco, California, USA	Issy les Moulineaux, France	Apple Inc., Apple, Mitten Rd., Burlingame, California, USA
	Information Link	http://jawbone.com	http://www.fitbit.com	www.withings.com	www.withings.com
Product released	Released(USA)	13-Nov-13	6-May-13	27-Jun-13	16-Sep-14
	Announced(USA)	13-Nov-13	7-Jan-13	6-Jan-13	16-Sep-14
	Present availability	Available	Available	Available	Available
Type	Smart watch	Watch style	Wearable/clip-on	Wearable/clip-on	Wearable/clip-on
General	Price in market	$150	$100	$100	$95
	Dimension (W×D×H)	6.1 × 6.1 inch	Small, 5.5 × 0.6 inch Large, 6.3 × 8.2 inch	1.7 × 0.87 × 0.33 inch	1.08 × 0.13 × 1.08 inch
	Weight	Small, 19 g large, 23 g	Small, 16.4 g large, 18.9 g	8 g	9.4 g
Battery	Type	$LiMnO_2$ 225mAh	Lithium polymer battery	Lithium-ion polymer	CR2032 coin cell
	Battery life	4–6 months	4–6 months	6 months	3 months
	Rechargeable battery	Yes	Yes	Yes	No
	Changeable battery	No	No	No	Yes
	Usable per one time charged (advertised)	Up to 10 days	Up to 14 days	Up to 14 days	Up to 180 days
	Full charging time	3 hours	4 hours	2 hours	No
Tracking Metric	Motion	Yes	Yes	Yes	Yes
	Step counting	Yes	Yes	Yes	Yes
	Distance	No	Yes	Yes	Yes
	Calories	Yes	Yes	Yes	No
	Sleep	Yes	Yes	Yes	Yes
	Heart rate	No	No	Yes	No
	Fitness analytics	Yes	Yes	Yes	Yes
	Wind	No	No	No	No
	3D mapping	No	No	No	No
	Speed	No	No	No	No
	SpO2	No	No	No	Yes
	Goal tracking	No	Yes	No	No

Features	Specifications	Jawbone Up24	Fitbit Flex	Withings Pulse	Misfit
Resistance function	Water resistance	Not too high	Yes	No	Yes (up to 30 m)
Synchronization	Sync type	Wireless (Bluetooth)	Wireless (Bluetooth)	Bluetooth	Wireless (Bluetooth)
	Sensor network	Bluetooth	Bluetooth	Bluetooth	Bluetooth
Screen and display	Screen type	Dual LED	Five LEDs	OLED (black lit)	12 LED and blink
	Touchscreen	Capacitive finger	Capacitive finger	Capacitive finger	Capacitive touch
	Screen size (inch)	No (LED bar)	No (LED bar)	1.69	No (12 LED Blink)
Sensor type	Three-axis accelerometer	Yes	Yes	Yes	Yes
	Three gyro sensors	No	No	No	No
	Magnetometer	No	No	No	No
	Pressure sensor	No	No	No	No
	GPS	No	No	No	No
	Altimeter	No	No	No	No
Alarm function		Yes	Yes	Yes	Yes
Data sharing		Yes	Yes	Yes	Yes
Material	Wearable body type	Rubber	Rubber	Rubber	Anodized aircraft-grade aluminum
Smartphone	Smartphone operation system	iOS 5.1 or greater, Android 4.0 (Ice Cream Sandwich) or later	Window Xp/Vista/7/8 Mac OS X 10.5 or above iOS/Android	Android 2.3.3 over or iOS	Pair to iOS only
UI interface	History tracking (days)	270 days	30 days	10 days	30 days
	Computer data storage (Web app)	No	Yes	Yes	Yes
Social network data Sharing	Data sharing	Only friends who you already have known	Yes	Yes	Yes

Table 1. The comparison table of features and function of four wearable devices.

Part 1. Satisfaction assessment of properties and features.

This section invited participants to provide a satisfaction rating score for the properties and features of each of the four devices. Factors to consider included the hardware, or general design, the user interface and UI app, the synchronicity, the battery, and the user-friendliness.

Part 2. Satisfaction scores for the device metric function.

This section invited participants to provide a satisfaction rating score for the metric function on each of the devices. This encompasses measures such as step count, distance, calories, sleep, and analysis of nutrition.

Section 2. Participants' personal opinions about the devices.

This section allowed participants to record their opinions on the positive and negative aspects of each device. The personal comments of the participants can then be presented subsequently.

2.3.2.2. Testing the devices for accuracy and repeatability

The functionality offered by each of the four devices is similar; the differences lie within the user interfaces, applications, and the algorithms used for calculations. The most important criteria from the perspective of the user are accuracy and repeatability, since these aspects will guide the users to reliability achieve their targets. However, the accuracy and repeatability of any of these devices will also depend to a certain extent of personal factors such as the weight, height, gender, and age of the user. The physical data will therefore be required along with the subjective perceptions of the users in order to determine the accuracy and repeatability of the four devices.

To conduct the test, the devices were placed on the participants' wrists as shown in **Figure 2**. Following the recording of test data during the experiment, the real data were then measured in terms of distance so as to compare with the recorded data from the devices in order to determine the accuracy.

The percentage of accuracy and repeatability for the four devices are presented in this paper. The repeatability was calculated using Cronbach's Alpha, SPSS program (SPSS V.2012, IBM Corporation, USA). Subsequently, we scaled scoring among the four devices from the best to the lowest, as explained in **Table 2**.

Experiment 1. Distance traveled and step counting of indoor walking.

Subjects wore the four devices (**Figure 2**) and then walked straight across the indoor experiment court. Total distance was 48 meters for ten trials per person. The data for step counting and distance represented for each device were collected.

Experiment 2. Distance traveled and step counting of treadmill running (jogging).

Subjects wore the four devices (**Figure 2**) and then ran or jogged on a treadmill at 8 km/h [13, 14] for 1 minute, repeated for five trials. The real data record from the treadmill was collected to compare with the real distance calculation from the treadmill's LCD.

Experiment 3. Step counting when walking up and down stairs.

Subjects wore four devices as shown in **Figure 2**; then walked up four flights of stairs, repeated the experiments for five times; and then walked down the stairs, repeated for five times.

Upon completion of the data gathering stage, scores were assigned to each device for accuracy and repeatability using a scale rating of one to four, where four indicates the best performance among the four tested products, as shown in **Table 3**.

Figure 2. The subjects wore all four devices to measure the accuracy and repeatability of results.

Scale (point)	Meaning
4	The highest accuracy or repeatability among the four devices
3	The second highest accuracy or repeatability among the four devices
2	The second lowest accuracy or repeatability among the four devices
1	The lowest accuracy or repeatability among the four devices

Table 2. Scale of accuracy and repeatability when compared among four devices for each experiment.

3. Results and discussion

3.1. User satisfaction

After each of the four 1-week test periods, the participants completed the evaluation form providing their Likert scores concerning the device attributes and qualities until UI application. The satisfaction scale applied is described in detail in **Table 3**.

Figure 3a shows the mean score for the five conditions of features, including device design, battery use, smartphone synchronization, UI applications, and ease of use. On the other hand, **Figure 3b** shows the mean and standard deviation score of the satisfaction when using the four main functions of each device, including step counting, sleep tracking, distance tracking,

Scale (point)	Meaning
5	Very useful and very satisfied
4	Moderately useful and moderately satisfied
3	Slightly useful and slightly satisfied
2	Less useful and less satisfied
1	Not useful and not satisfied

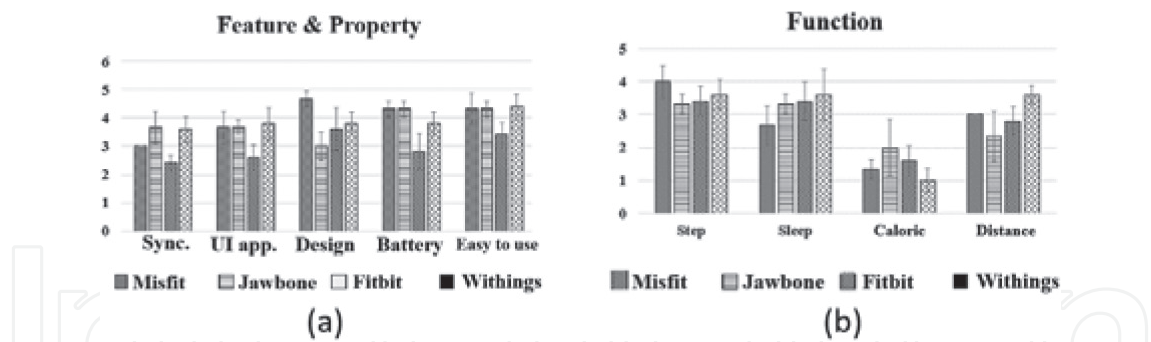**Table 3.** The scale of evaluation and corresponding meanings.

Figure 3. (a) Bar graph comparison of mean and standard deviation of the satisfaction score by subjects when using the devices. (b) Bar graph comparison of mean and standard deviation of the satisfaction score by subjects when using the devices.

and caloric analysis. The case of heart rate analysis does not exist in the evaluation score because only the Withings Pulse possessed this function.

From the subjective results, the Withings Pulse device had the highest satisfaction score, followed by the Misfit Shine, Jawbone Up24, and Fitbit Flex.

The results in **Table 4** show the opinions, which imply that subjects gave similar answers to two persons about the features and functions of each device.

Opinion about features	Jawbone Up24	Fitbit flex	Withings pulse	Misfit Shine
Design	Light and good for any sport	Device design is good and sleek; it is good for any sports	Design is not attractive, but the fabric band can help to hold it as wrist band	Design is very attractive, beautiful, and fashionable
Display	Easy to tap the screen to active	Easy to tap on screen to active	Display is big and shows the activity tracking without any smart phone sync	Display is as clock; it can also be used as a watch, but in the sunshine it is hard to see the LED display
Water resistant	It is water resistant, but according to the manual, it is less water proof	It can be used to take shower without worrying	According to manual, it is not water resistant	It is designed for sports as swimming; water resistant is too high
UI app	1. Tips of app and how to use always shown on home screen	1. UI app is colorful and has fun display, easy to use	1. Display is easy to use and colorful	1. Display is beautiful and easy to understand
	2. Enjoyable fitness tracker	2. Nutrient analysis is very detailed	2. Dashboard log is easy to check all activity	2. It has goal tracker to lead you to know your daily activity
	3. Dashboard shows the overall daily activity	3. Dashboard shows the overall daily activity	3. The heart rate function is good to check your health status	3. App can be shared to your friends; it shows how your friends seek the goal

Opinion about features	Jawbone Up24	Fitbit flex	Withings pulse	Misfit Shine
Metric function	Sleep tracking is its main function because the sleep tracking report is very detailed, but it is difficult to use	Food and nutrient calculation is its main function; it is very easy to use	The Pulse O2 measurement is its main function; it can help you detect your heart status	The goal tracking is its main function; you can check how your status to seek the goal
Battery	It can be charged only on the USB cable	It has the battery indicator to check the battery status, but it has high battery consumption	It has battery indicator to check battery status; battery can be used in too many days	It is comfortable; no need to charge the battery
Synchronization	Slow synchronization	Slow synchronization but always lost connection	Fast synchronization, data can send via Bluetooth and WiFi	Fast synchronization but easy to lose connection
Others (disadvantage/ cons)	1. The devices required smartphone to display	1. It required smartphone	1. Design is not modern	1. It required smartphone
	2. No display on itself	2. Slow synchronization	2. If the battery of witlings is low, the device cannot connect. The data transfer which is shown on the smartphone is inaccurate	2. It has slow synchronization, not always updated real time
	3. Sleep tracking results are difficult to use and nonautomatic	3. The device is confusing sometimes; it needs to be reset	3. The sleep tracking is not automatic	3. Sometimes it gave inaccurate display
	4. Cannot share the data through social network	4. Tracking problem when walking up- or downstairs	4. Not water proof	4. Tracking problem when walking up- or downstairs (inaccurate)
	5. Most expensive among four devices	5. High battery consumption	5. Automatic loss of syncing	5. The display does not always respond to finger tapping
	6. It is not fully waterproof	6. Data is not updated sometimes	6. Screen is difficult to see in sunlight	6. No nutrient analysis
	7. Slow Synchronization	7. Calories count is not easy to use and only European foods are in the database	7. No Nutrient analysis	7. Always disconnected from mobile phone

Table 4. Comparison table of user feedback (summarized from seven subjects for each device).

From **Table 4**, it is apparent that all four devices were both satisfactory and unsatisfactory to the subjects. As mentioned in Topic 3.2, the summary of the opinions came from the similar meaning answers from two or more subjects. The most clearly apparent problem across all devices was the automatic loss of synchronization, which presents a problem in updating data, and leads to incorrect reports. However, all of the participants were able to use all of the devices easily with minimal instruction, or less, so the user-friendliness was good in all cases. The summary of the different claims from the reviewers on various commercial websites reviewing the devices is shown in **Tables 5–8**. Considering the five top-ranked sites from a Google search, it is clear that the leading reviews are well known due to the large numbers of people visiting those top-ranked sites to investigate wearable devices. The comments and descriptions of the reviewers can inform customers who might wish to purchase one of the devices for themselves. The draw-back is that although the reviews can appear helpful, it is difficult to know whether the views have been influenced by the companies themselves or if they are in fact genuine independent perspectives. It is possible for an opinion to come only from one reviewer who used a product.

This section is explored because of the pros and cons of using reviewer claims, whether or not they may be similar or different than the customer's and seven subjects' opinions in this study. **Tables 5–8** shows the summarized data of advantages (pros) and disadvantages (cons) for each of the four devices from reviewers on the websites.

Jawbone UP24 subjects' opinions and the reviewers imply that it has a good design and fits comfortably. The UI app is colorful and easy to understand. The sleep tracker is very smart and also has good alarm functions. However, disadvantages of the device (cons) include the design lacking a screen; it is not fully water proof, and the battery charger is complex.

Withings Pulse has good primary features, such as the heart rate function. The display itself is big and can show the results tracking. The data log uses Bluetooth syncing or wireless for automatic updating. The Withings design does not, however, provide an attractive case, with direct sunlight making it hard to read the display. Furthermore, there is no automatic sleep tracking function.

Fitbit Flex has a slender and attractive design, is wholly waterproof, and is equipped with good social features. However, the Fitbit Flex has weak points in that it has no screen; the food log and calories tracking are not easy to use, and the tapping screen is sometimes confusing.

Misfit Shine looks both fashionable and elegant. It is ideal for watersport enthusiasts since it is fully waterproof. It offers a goal tracking feature which motivates users to achieve their targets. The battery is exchanged rather than recharged. However, the device works only with iOS, and while there are plans to introduce Android compatibility, this has not yet taken place. A smartphone is necessary to check the tracking status, and there are sometimes problems which arise when poor syncing from device to smartphone results in inaccuracies.

3.2. Accuracy and repeatability of the four devices

From **Table 9**, it can be seen that the Withings Pulse achieved the best results for the accuracy and repeatability of measurements for indoor walking, at 99.9% for accuracy and 86% for repeatability. **Figure 4** shows the results for all of the four devices. The lowest scores for accuracy and repeatability were measured for Misfit.

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantage (cons)
Weebly	Jawbone Up24 review	8-Nov-14	[11]	1. Wireless syncing	1. Social sharing: can only add friends you already know
				2. Can be used in the shower	2. No website interface, only phone app
				3. Deep sleep and light sleep data	3. Hair can stuck in cap button
				4. "Smart Wake" alarms for naps	4. Overcount arm movement as steps
				5. Usability design	5. No screen
				6. Holds battery charge for up to 7 days	—
Raphael Mumford	Smart activity tracker, Jawbone Up24 review	Not mentioned	[12]	1. Well-designed band fits your wrist comfortably	1. No measurement of stairs climbed
				2. Long lifetime battery (up to a week for per full-energy charging)	2. Just for iOS devices
				3. Wireless syncing via Bluetooth without any hassle	—
				4. Quick charging	—
				5. Smart alarm	—
				6. Expandable storage capability	—
				7. Price is cheap	—
Matt Swider	Jawbone Up24 review	24-Mar-14	[13]	1. Wireless syncing added	1. No display for on-demand stats
				2. Stylish and lightweight	2. Doesn't have a web app
				3. Very soft rubber for comfort	3. Works with just ten Android phones
				4. iOS and Android compatible	4. 2.5 mm stereo jack for charging
Michael Sawh	Jawbone Up24 review	26-Mar-14	[13]	1. Bluetooth smart support for real-time syncing	1. No built-in screen
				2. Slim, stylish design	2. Shorter battery than Jawbone UP
				3. Great silent alarm feature	3. App is sluggish at times
				—	4. Not waterproof

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantage (cons)
Matthew Miller	Jawbone UP24	6-Dec-14	[14]	1. Well-designed band that fits comfortably long battery life	1. No altimeter to measure stairs climbed
				2. Flawless syncing via Bluetooth	2. Limited just to iOS for now
				3. Integrated Microsoft Office software	3. Hangs up on jackets and long sleeve shirts
				4. Charges up quickly	—
				5. Great sounding front facing stereo speakers	—
				6. Expandable storage capability	—

Table 5. Summary of pros and cons from reviewer opinions for the jawbone UP24.

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantages (cons)
Weebly	Withings Pulse smart activity tracker review	Not mentioned	[15]	1. Captures heart rate information	1. Not shower-safe
				2. Captures flights of stairs climbed and elevation climbed	2. Easy to misplace (leave in pockets, etc.)
				3. Check running stats (duration and distance traveled) in real time	—
				4. Automatic wireless syncing	—
				5. Captures sleep (duration, quality, light versus deep sleep, interruptions)	—
				6. Screen with constant feedback	—
				7. Discreet and multiple ways to wear	—
				8. Battery charge lasts up to 14 days	—
				9. App also pulls in data wirelessly	—
				10. Internet site available for Withings devices	—

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantages (cons)
Raphael Mumford	Withings Pulse wireless activity tracker review	Not mentioned	[16]	1. Easy to clip on something thanks to a silicone and metal clip	1. Not automatically detect the time and switch to sleep mode
				2. Large OLED screen touch screen and easy history browsing	2. Lack of silent alarm
				3. Free iOS and Android apps	3. The screen is not easy to read under the sunlight
				4. Accurate heart rate monitoring	4. Syncing to PC is impossible
				5. Low power consumption. The battery has a long lifetime of 2 weeks	—
				6. Charging easily via a standard micro-USB to USB power cable on a computer or on a smartphone	—
				7. Free account on Withings.com to store your health and fitness data	—
				8. Worn as a wristband to track your activity and sleep	—
				9. Log your foods and weight, and get the perfect balance between activity and nutrition	—
DC Rainmaker	Withings Pulse In-Depth Review	21-Nov-13	[17]	1. Can record resting heart rate quickly and easily	1. The unit is a bit chubbier than some others
				2. Display is clear and easy to understand	2. Does not track heart rate all 24 hours, only on demand
				3. Good battery life	3. Does not automatically go from sleeping mode to nonsleeping, must switch over manually
				4. Good ability to connect to third-party platforms/sites	—

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantages (cons)
Mikey Campbell	Review: Withings Pulse with built-in heart rate monitor	4-Nov-13	[18]	1. Variety of sensors	1. Lack of meaningful data presentation
				2. Impressive data accuracy	2. Display lag, touchscreen issues
				3. Flexible carry options	3. Wear ability limited to belt clip
Julie Strielmeier	Withings Pulse Activity tracker review	23-Aug-13	[19]	1. Size of the pulse	1. Syncing problem
				2. Can see all the important info right on the device itself instead of like some devices	2. Sleep data is not always accurate, and the detailed data could use some beefing up to show more info
				3. Wireless syncing is a real plus too	3. It does not work with a stand along computer
				4. The built-in heart rate sensor is super easy to use	—

Table 6. Summarized data of pros and cons from reviewer opinions for the Withings pulse.

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantages (not so cons)
Weebly	Fitbit Flex review	10-Aug-14	[20]	1. Comfy wristband form factor	1. Does not track flights of stairs (like the FitBit One)
				2. shower-safe water resistance	2. Always visible if worn with short sleeves
				3. Very adjustable wristband	3. No screen on device to show you detailed information on goal progress
				4. Progress lights tell you how close you are to reaching your daily goal	4. Very hard to attach to the wrist and can pop off (while canoeing, for me)
				5. Wireless syncing	5. Have to tap band repeatedly to enter/exit sleep mode or to stop the silent alarm
				6. Great integration with existing fitness apps like MyFitnessPal	6. Chopping veggies can trigger sleep mode
				7. Strong social features including adding friends with a FitBit device or other FitBit users, a competition	—

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantages (not so cons)
Raphael Mumford	Fitbit Flex wireless activity Review	Not mentioned	[21]	1. Slim and stylish design for the perfect fit	1. Lack of stair tracking
				2. Track everything relating to your activities and sleeps, except for stairs quantity	2. A tiny LCD display is not included
				3. Waking up silently thanks to gentle vibration	—
				4. Five built-in LED indicator lights for better monitoring of your progress	—
				5. Water resistance is included	—
				6. The Fitbit App for iPhone and Android devices to track your real-time stats, set goals, log food and other workout information, and then represent your sleep trends	—
				7. Connecting and competing with other athletes for a better motivation	—
				8. A long lifetime battery of 5–7 days per charge	—
				9. Two options in size and two options in color you can choose from	—
Articles by Suzie	Fitbit Flex review	Mar 15	[22]	1. It is easy to wear all the time	1. Only charge the tracker with the USB cable
				2. Water resistant	2. It takes a lot of work in the beginning to establish your food menu
				3. Upload status automatically through the Bluetooth or dongle	3. Sometimes have trouble tapping the tracker into sleep mode
				4. Notification alert to let me know when my battery is running low.	—
				5. Learning curve to get the most from it; the Dashboard is a colorful and has fun display of my activity	—
Bethany Gordon	Fitbit Flex	Only year mentioned (2015)	[23]	1. Excellent interface	1. This device does not have a screen
				2. Excellent app	2. Only view your data from your computer or your phone.

Table 7. Summarized data of pros and cons from reviewer opinions for the Fitbit flex.

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantage (cons)
Weebly	Misfit shine activity tracker review	8-Nov-14	[24]	1. Waterproof	1. Sleep data is basic
				2. Wireless data transfer (when placed near the device)	2. Shine attachment can come unsecured (can pop out of sports band)
				3. Can track swimming and cycling	3. Time-telling feature suggests this could replace a watch, yet it lacks all other watch features including alerts
				4. Elegant aluminum design	4. Limited info on "screen": does not have a full digit-based display
				5. On-device feedback to let you know how close you are to reaching a goal	5. Shine's tapping-based interface can be frustrating to use
				6. No recharging. Just replace the watch battery when it runs out (~4–6 months)	—
				7. Partnership with Pebble watch allows you to use the Pebble as a Misfit Shine	—
				8. Social features including a leaderboard, profile, and newsfeed	—
Bethany Gordon	Misfit Shine	Only year mentioned (2015)	[25]	1. The interchangeable design	1. Tapping the screen is the only way to see your progress
				2. Comfortable band making the Misfit Shine extremely easy to use	2. The Shine does not always respond to tapping
				3. Convenient to wear	3. It has to sit on your arm a certain way to display time and daily progress
				4. Water resistant	—
Kristen Buck	Misfit Shine	Only year mentioned (2015)	[26]	1. Misfit Shine is about the size of a quarter and undeniably attractive.	1. The Misfit Shine only works for iOS
				2. Water resistant	2. Does not have an altimeter to count how many flights of stairs you climb
				3. Great activity monitor for swimmers and surfers	3. Not compatible with Android devices
				4. Can wear it in different ways to track different activities more accurately	—

Reviewer name	Site name	Reviewed date	Reference site	Advantages (pros)	Disadvantage (cons)
Jill Duffy	Misfit Shine	10-Dec-13	[27]	1. Best looking activity tracker	1. Limited data analysis
				2. Includes clip and wristband mounts	2. No integration with other services
				3. Functions as a watch	3. No Web app
				4. Fully waterproof for swimmers	4. No syncing between iOS and Android apps
				—	5. Dashboard lacks weight-tracking and calorie counting
Mikey Campbell	Review: Shine activity monitor	12-Nov-13	[28]	1. Great design	1. Clunky tagging method
				2. Easy to understand graphical readout	2. Light in features
				3. Long battery life	3. LEDs unusable in bright sunlight

Table 8. Summary of pros and cons from reviewer opinions for the misfit Shine.

Experiments and results	Devices	Accuracy (%)	Repeatability
Indoor walking straight	Jawbone	97.7	0.55
	Withings	99.9	0.86
	Misfit	92.4	0.69
	Fitbit	99.6	0.72
Walking up/downstairs	Jawbone	97	0.89
	Withings	97.2	0.83
	Misfit	97.8	0.79
	Fitbit	96.4	0.81
Walking on treadmill	Jawbone	97	0.89
	Withings	97.2	0.83
	Misfit	97.8	0.79
	Fitbit	96.4	0.81

Table 9. Comparison of accuracy and repeatability for the devices.

The total scores for each device are shown in **Table 9** and **Figure 4**. The Withings Pulse has the highest score for both repeatability and accuracy. The lowest accuracy and repeatability were recorded by Misfit. With regard to opinions from seven subjects and also the table of reviewers, we concluded that both the Fitbit and the Misfit have difficulties in detecting when the
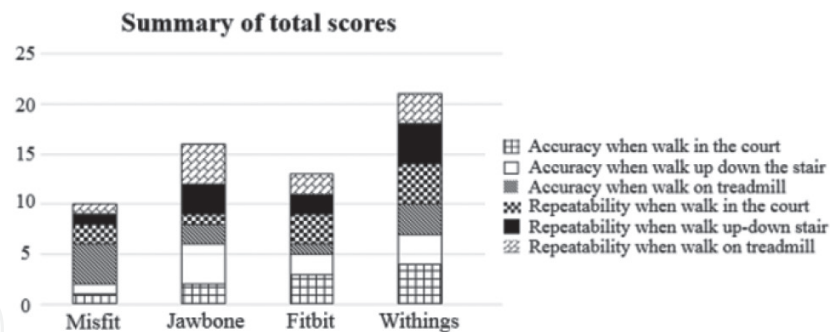
Figure 4. The summary of the accuracy and repeatability scores among the four devices.

wearer is ascending or descending steps. Along with the subject's experiments in **Table 5** and **Figure 4**, the scores from experiments of walking up and down stairs are both lowest in cases of accuracy and repeatability. This resulted in the overall scores for the Misfit and the Fitbit being the lowest among the four wearable devices in terms of repeatability and accuracy.

The total scores for each device are shown in **Figure 4**. The Withings Pulse has the highest score for both repeatability and accuracy. The lowest accuracy and repeatability were recorded by Misfit.

4. Discussion and conclusion

We attempted to evaluate the best wearable device from the four devices selected. This study focused on both objective and subjective methods to get the physical comparison results. The results are independent of manufacturers' claims. The main two sections of experiment testing verified the quality of the devices, both objectively and subjectively.

Section 1. Eight categories were classified in the form for evaluation of satisfaction levels: synchronization, hardware design, UI app, sleep tracking, step count, nutrition analysis, calories, battery, and user-friendliness. The most satisfying device based on the participants' rankings was the Withings, followed the Misfit, Jawbone, and Fitbit.

Further to the information gathered in Section 1, a summary was compiled from the viewpoints of the seven participants and online reviewers. The summary revealed that each device had its own strengths and weaknesses. The evaluation form and satisfaction scores thus allowed the subjective records of genuine users to be presented for each of the four devices. The opinions of the participants and those of the online reviewers were shown to be similar, leading to the following conclusions:

Jawbone UP24 is well designed and fits comfortably for the subjects. The UI app is colorful and easy to understand. The sleep tracker is very smart and also has good alarm functions. However, disadvantages (cons) include the design not having a screen, it is not water proof, and the battery charger is very complex.

Withings Pulse has good features such as the heart rate function, which can detect pulse rate. It is just one of the functions that the Withings has. The display on the Withings device is large enough to show the results tracking. The data log can be updated automatically via

Bluetooth syncing or wireless. The design, however, is not particularly attractive, since it is hard to read the display under exposure to sunlight and the sleep tracking feature does not work automatically.

Fitbit Flex has a slender and attractive design, is wholly waterproof, and offers a number of social features. However, the Fitbit Flex has weak points. It has no screen, the food log and calories tracking are not easy to use, the food log is hard to learn for beginners, and the tap screen is sometimes confusing.

Misfit Shine has an attractive, elegant, and fashionable design. It is fully water proof and especially good for water sports. The goal tracking function leads the user to achieve the goal, and the battery does not need to recharge, only exchange. In contrast, the Misfit Shine can only be used with iOS. Although compatibility with Android is a planned future feature, it has not yet been implemented. A smartphone is necessary to display the tracking status since the device does not have its own display. When loss of syncing with the smartphone occurs, this can result in data inaccuracies.

Section 2. The experiments compared the accuracy and repeatability of the devices awarded among four wearable devices. The score four points for the best accuracy and repeatability. The score three, two, and one point for the second, third, and fourth device, respectively. The most accurate and repeatable device was the Withings, second Jawbone, third Fitbit, and fourth Misfit.

In contrast, Misfit had the highest score for design and hardware. Thus, physical design is also appreciated by users in addition to other devices.

Therefore, the Withings device provided the greatest satisfaction and was the most user-friendly from the perspective of the users. It was also the highest ranked for accuracy and repeatability in step count and distance tracking. Tracking accuracy is vital in fitness tracking, but in personal tracking, there are differences which stem from age, gender, weight, and height. The tracking of daily activities including sleeping, waking, or running will also be important, and the results of the tests indicate that the greatest accuracy is achieved by the Withings device in all these categories for accuracy and repeatability.

As the results showed, the cause that made the Misfit Shine and Fitbit Flex have the lowest score of accuracy and repeatability was stair tracking. These two devices could not track activity when the subjects walked on stairs or climbed. For this reason, users were disappointed in these devices.

In this study, it was unclear by inspection of the deep or shallow sleep of the subjects whether the wearable devices could measure accurately. Thus, true value comparison was not shown in this research. However, future studies may advance this knowledge.

The results in this study relative to step counting and others are subjective enough to assist in the buying process for potential wearable device purchasers. One more fact from the seven subjects' opinions is that four of the seven subjects would not buy this kind of wearable device. It interferes with their arm while in use and is uncomfortable with syncing the data log for daily tracking. One more important reason is that data gave uncorrected reports because of automatic loss of syncing.

Nowadays, wearable technology has the greatest potential impact in the fields of health and fitness. However, it can also be influential for gaming and other forms of entertainment.

Wearable technology can create a vividly realistic and immersive environment in real time. This concept is not new. Modern prototypes are moving away from bulky technology, such as large goggles and backpacks, toward smaller, lightweight, and more mobile systems.

On the author's viewpoint, the most comparable of the wearable device is that it cannot display itself but needs the smartphone to involve the metric data and reports. However, the storage of mobile phone to store and display the results is bigger, but it is inconvenient to use both at the same time. And yet, presently many fitness-tracking applications are available through the online store for free without any special or specific device. It is very convenience to whom that focuses in their healthy or fitness tracker. Even though the report of it is not guarantee 100% of accuracy, it is the easiest way to track their activity without any payment. Thus, the companies who produced the fitness tracker or wearable devices to the market in this highly competitive market will continuously develop new eye-catching products and reduce errors using the voices and opinions of users from this study to reach a wider market in the future. The relationship between technology and esthetics must go together, such as unobtrusive design, very sleek and modern and light weight, waterproof function, and many choices to recharge batteries. Basic activities such as walking or climbing stairs require accuracy and repeatability, while it is also necessary to accurately measure physical parameters such as pulse, heart rate, body temperature, and breathing rates. These features should be added in cases where they are not yet available. At present, the market for wearable devices is growing rapidly, and this will drive the further development of the technology to deliver the features and attributes demanded by users. This study has therefore addressed the fact that consumers need access to accurate and reliable information with regard to the latest gadgets available on the market and the performance of those devices.

Acknowledgements

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