# Comparison of Oura Smart Ring Against ActiGraph Accelerometer for Measurement of Physical Activity and Sedentary Time in a Free-Living Context

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Smart rings, such as the Oura ring, might have potential in health monitoring. To be able to identify optimal devices for healthcare settings, validity studies are needed. The aim of this study was to compare the Oura smart ring estimates of steps and sedentary time with data from the ActiGraph accelerometer in a free-living context. A cross-sectional observational study design was used. A convenience sample of healthy adults (n = 42) participated in the study and wore an Oura smart ring and an ActiGraph accelerometer on the non-dominant hand continuously for 1 week. The participants completed a background questionnaire and filled out a daily log about their sleeping times and times when they did not wear the devices. The median age of the participants (n = 42) was 32 years (range, 18–46 years). In total, 191 (61% of the potential) days were compared. The Oura ring overestimated the step counts compared with the ActiGraph. The mean difference was 1416 steps (95% confidence interval, 739–2093 steps). Daily sedentary time was also overestimated by the ring; the mean difference was 17 minutes (95% confidence interval, −2 to 37 minutes). The use of the ring in nursing interventions needs to be considered.

**KEY WORDS:** Accelerometer, Physical activity, Sedentary, Smart ring, Validation

For healthcare professionals, it is often important to map holistically all the aspects associated with the patient's well-being. Physical activity is one of the essential elements related to a healthy lifestyle; an adequate level of physical activity promotes, for example, the ability to function and weight control. Furthermore, physical activity reduces the risk for certain diseases. Inadequate physical activity, however, is a global phenomenon.[1] Only some adults, as well as children and adolescents, achieve the internationally recommended levels of physical activity. Low levels of physical activity and excessive sedentary behavior, defined as sitting, reclining, or lying down while awake, are associated with many health-related risks such as diabetes and cardiovascular diseases.[1,2] It is also typical for individuals to overestimate the volume and intensity of their physical activity when reported subjectively.[3,4] Furthermore, possible changes in health behaviors require time. Therefore, objective and long-term measurement of physical activity is needed. Commercially available small and lightweight wearable activity trackers might be useful in healthcare settings as well as in nursing interventions. It is also suggested that nurses could use activity trackers as an opportunity to encourage people to engage in physical activity.[5]

Commercially available wearable activity trackers have become very popular for monitoring physical activity. Following many wrist-worn smart bands and smartwatches, a finger-worn smart ring has come to the market. Smart rings such as the Oura ring (https://ouraring.com/) provide a different option to more traditional smartwatches and smart bands. Rings might attract users as they are more like pieces of jewelry instead of watches. Wearable trackers might have the potential to facilitate physical activity in individuals; however, multifaceted interventions seem to have a greater effect compared with a wearable activity tracker only.[6,7] Previously, wrist-worn activity trackers have shown value for patients with chronic diseases, such as cancer or diabetes, or specific populations such as children or older adults.[8] Users' feedback has been mostly positive; users have found activity trackers appealing and useful for increasing their levels of physical activity.[9]

In addition to healthcare settings, wearable activity trackers are also used in measuring for research purposes, as they are comfortable and easy to use in participants' daily life and provide real-time feedback as well as enable continuous assessment of physical activity for long periods of time.[6,8,10,11]

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The accuracy of wearable trackers is essential for individuals, nurses, and other healthcare professionals, as well as researchers; therefore, establishing the validity and accuracy of activity trackers is important.[12] The performance of activity trackers, especially in a free-living context, should be examined further to identify optimal devices, for example, for research purposes.[13] New devices are released every year, and technological advances in those provide new possibilities to researchers.[12] The majority of previous validity studies have been conducted with wrist-worn trackers.

Studies about the Oura smart ring have provided promising results about its validity concerning sleep in laboratory conditions against polysomnography both in adults[14,15] and in adolescents,[16] as well as in a free-living context against wrist-worn actigraphy in a healthy adult population.[17,18] It has been stated that sleep staging in the Oura ring needs improvement.[16] Regarding sleep quality, the correlations between the Oura ring and other devices measuring sleep were weak in a pilot study aiming to monitor sleep in the natural environment. It is, however, notable that no gold standard measure was used.[19] Nocturnal heart rate and heart rate variability of the Oura ring have been validated against electrocardiogram (ECG) with home-based monitoring. Very high agreement was observed between the ring and electrocardiogram measurements.[20] Furthermore, the Oura ring has shown potential in monitoring the menstrual cycle based on nocturnal skin temperature.[21] The Oura ring has also been tested in detecting COVID-19[22] and predicting symptoms of depression and anxiety.[23] Aside from a preprint study, which was not peer reviewed, there are no previous publications about the validity of the physical activity or sedentary time measures of the Oura ring. The preprint by Henriksen et al[24] showed that the step count was overestimated by the Oura smart ring compared with the ActiGraph placed on the hip.

The aim of this study was to compare the Oura smart ring estimates of steps and sedentary time with data from the ActiGraph accelerometer with healthy adults in a free-living context.

## METHODS

### Design and Setting

A prospective observational study design was performed in southern Finland during July-August 2019. Reporting the study adheres to the STrengthening the Reporting of OBservational studies in Epidemiology reporting guidelines.

### Recruitment and Participants

A convenience sample of healthy adults between 18 and 55 years old was recruited for the study. Potential participants were excluded if they had (1) a diagnosed heart disease, (2) restrictions regarding physical activity, (3) the symptoms of illness at the time of recruitment, or (4) any restrictions of using the devices at work.

The research assistants scheduled a meeting with each interested and eligible participant. The purpose of the study was explained, and written informed consent was obtained. The participants were asked to wear an Oura smart ring and an ActiGraph accelerometer (reference device) continuously for 1 week. The Oura smart ring was placed on a finger of the non-dominant hand, and the ActiGraph was worn on the wrist of the non-dominant hand; thus, both devices were worn on the same hand.

Altogether, 46 participants (23 females and 23 males) were enrolled in the study. One participant was excluded from the analyses due to not wearing the ActiGraph, and three participants were excluded because they did not have enough data for the analyses. Thus, the final sample size was 42.

### Measures

The Oura smart ring (Ōura Health Ltd, Oulu, Finland) is a commercial tracker device for monitoring activity, sleep, heart rate, and heart rate variability. The Oura ring includes one built-in photoplethysmography sensor and an inertial measurement unit. The ring is light (4-6 g), waterproof, and easy to use. The battery life is 6 days. The data are automatically sent to the mobile app (compatible with both Android and iOS) and transferred to the cloud server.

The ActiGraph accelerometer (Pensacola, FL, USA) is a non-commercial device for research purposes and was used as a reference measure in this study. The battery life is 25 days. The ActiGraph measurements are based on motion sensors that provide data for numerous activity measures. In this study, a wrist-worn ActiGraph wActiSleep-BT was used as it was considered a valid measure. The ActiGraph accelerometer worn on a non-dominant wrist has been shown to overestimate the daily step count by approximately 10% when compared with video observation in free-living conditions.[25]

ActiGraph data were downloaded and converted into 60-second epochs using ActiLife software, version 6.13 (ActiGraph, Pensacola, FL). Sleep time was defined using the algorithm available in ActiLife[26] and non-wear time by the Choi algorithm[27]; both sleep and non-wear time were excluded from the analyses. Sedentary time was defined using the count cut-point value of <1853 vector magnitude counts per minute, which is validated for triaxial accelerometers worn on a non-dominant wrist against a thigh-worn triaxial activPAL accelerometer.[28] Step count was calculated using ActiLife's step counting algorithm without the low-frequency extension. The Oura ring provides various well-being and health-related parameters, including sleep duration, step counts, non-wear time, rest duration, and inactive time per day. We used the step counts per day values provided by

Oura as a measure of physical activity. The sedentary time was also computed as the time when the user was inactive or resting during the day. Moreover, we calculated the wear time per day by subtracting the sleep time and non-wear time from 24 hours. A valid day was defined as a measurement day with a minimum of 10 hours of waking wear time of both the ActiGraph and Oura.

### Data Collection

The participants were asked to wear the devices continuously for 1 week in their normal daily life. Verbal guidance and written instructions about using the devices were provided to all participants. Both devices were waterproof; thus, wearing them during a shower or swimming was possible. However, the participants were asked to remove the devices for the sauna. Participants were blinded to the data; they could not follow their activity, such as step count, as the devices had no display or synchronized software available for the participants. The data regarding physical activity were stored in the devices and downloaded after the data collection week by the researchers.

During the study week, the participants were asked to fill in a daily log to record waking time, bedtime, and the periods when they had possibly removed one or both of the devices.

A short questionnaire was completed during the recruitment meeting. The questionnaire included questions about background characteristics (age, weight, height, marital status, education, working status, and smoking) and a question about the frequency of physical activity.

### Ethics

The study protocol received a favorable statement from the Ethics Committee for Human Sciences at the University of Turku (Statement 44/2019). Both verbal and written information was provided to the participants before obtaining the written informed consent. All participants had the right to withdraw from the study at any phase and without any specific reason. Each participant was given a gift card (20 euros) to a grocery store to compensate for their time and effort used for the data collection period.

### Data Analysis

In total, 289 valid days were recorded by ActiGraph and 264 by the Oura ring. The number of common valid days for both devices was 232. Based on the participants' diaries, 41 days were further excluded from the analyses due to the differences of more than 10 minutes in wake wear time between the devices, resulting in an analytical sample of 191 days.

Hierarchical linear mixed method was used to determine the mean difference between the devices. The Pearson correlation coefficients on pairwise step counts and pairwise sedentary time parameters were obtained to evaluate the linear correlation between the ring and the ActiGraph. We also utilized a linear regression analysis method. In this regard, the data of the devices were fit to linear regression lines. Then, $r^2$ values were calculated to show the scatter of the data around the lines. In addition, the Bland-Altman analysis was used to investigate the agreement between the devices. Bland-Altman provides the mean bias and ±95% confidence intervals of the step counts and sedentary time collected by the devices. *P* value lower than .05 was considered statistically significant.

## RESULTS

### Participants

A total of 42 participants participated in the study, and 191 days (mean, 4.5 days per participant) were compared. The median age of the participants was 32 years, ranging from 18 to 46 years. Their median body mass index was in the normal range; however, the sample also included participants with very low and high body mass index (Table 1).

### Step Counts

The Oura ring significantly overestimated the step counts compared with the ActiGraph, $P < .001$ (Table 2). The mean difference between the Oura ring and the ActiGraph was 1416 steps (95% confidence interval, 739–2093 steps) per day. Bland-Altman plots are presented in Figure 1, showing the mean difference between the tested device and the

**Table 1.** The Characteristics of the Participants (N = 42)

| Variable | Median (Range)/n (%) |
|---|---|
| Age, median (range), y | 32 (18–46) |
| BMI, median (range), kg/m$^2$ | 24.2 (18.9–47.0) |
| Married/cohabiting, n (%) | 33 (79) |
| Education level, n (%) | |
| Elementary school | 1 (2.5) |
| Secondary/vocational school | 9 (21) |
| Polytechnic | 10 (24) |
| University | 21 (50) |
| Missing information | 1 (2.5) |
| Working status, n (%) | |
| Employed | 32 (76) |
| Unemployed | 1 (2.5) |
| Student | 8 (19) |
| Other | 1 (2.5) |
| Smokers, n (%) | 4 (10) |
| Physical activity, n (%) | |
| Daily or almost daily | 12 (29) |
| Couple of times per week | 22 (52) |
| Maximum of once per week | 8 (19) |

Abbreviation: BMI, body mass index.

**Table 2. Mean Step Counts and Sedentary Time per Day and Mean Difference of Both Variables by the Oura Ring and the ActiGraph**

| | Step Count | | | Sedentary Time, min | | |
|---|---|---|---|---|---|---|
| | Mean (95% CI) | Mean Difference (95% CI) | *P* | Mean (95% CI) | Mean Difference (95% CI) | *P* |
| Oura ring | 12 769 (12 137–13 401) | 1416 (739–2093) | <.001 | 552 (535–568) | 17 (−2 to 37) | .049 |
| ActiGraph | 11 402 (10 970–11 834) | | | 528 (513–543) | | |

Abbreviation: CI, confidence interval.
*P* values are from paired *t* tests.

ActiGraph. For the Oura ring, the 95% limits of agreement were from −4432 steps to 7264 steps.

The Pearson correlation test showed a high positive linear correlation between the ActiGraph and the Oura ring ($r$ = 0.83, $P$ < .001). Moreover, the step counts of the ring were evaluated using regression analysis. Figure 2 shows the regression lines in red. The $r^2$ of the ActiGraph and the ring is 0.7, showing that the data are around the regression line. The ideal line (ie, $y = x$) is also indicated in black to show the best scenario where the step counts of the two sources are identical.

### Sedentary Time

Daily sedentary time was overestimated by the Oura ring, $P$ = .049 (Table 2). The mean difference between the Oura ring and the ActiGraph was 17 minutes (95% confidence interval, −2 to 37 minutes) per day. Bland-Altman plots are presented in Figure 3. For the Oura ring, the 95% limits of agreement were from −220 minutes to 255 minutes. Pearson correlation test showed a moderate linear correlation between the ActiGraph and the Oura ring ($r$ = 0.61, $P$ < .001). We also used the regression analysis to evaluate the sedentary time of the ring compared with the ActiGraph. The regression line (in red) and the ideal line (in black) are shown in Figure 4. The $r^2$ of the ActiGraph and the ring was 0.37.

## DISCUSSION

This validation study aimed to compare the Oura ring with the ActiGraph device regarding daily step count and sedentary time in free-living conditions. The results showed significant differences between the estimates of steps and sedentary time from the devices. The Oura ring overestimated both the step counts and sedentary time. The mean difference in step counts was 1416 steps per day, and that in sedentary time was 17 minutes per day. The different algorithms used in the devices may be one explanation for the detected differences in measured parameters. Although the devices were worn on the same hand, the Oura ring was worn on the finger and the ActiGraph was worn on the wrist; thus, the movements detected may differ, which might explain part of the differences.

The Oura ring overestimated the step count, which was also stated in a previous study comparing a hip-worn ActiGraph with the Oura ring.[24] The smaller mean difference detected in this study might be explained by the reference device worn on the same hand as the Oura ring, not on the hip, as in the study by Henriksen et al.[24] Based on these results, the Oura ring cannot unambiguously be recommended to replace the ActiGraph in measuring step counts if the accurate number of steps is the priority. The systematic difference in the step count between the ActiGraph

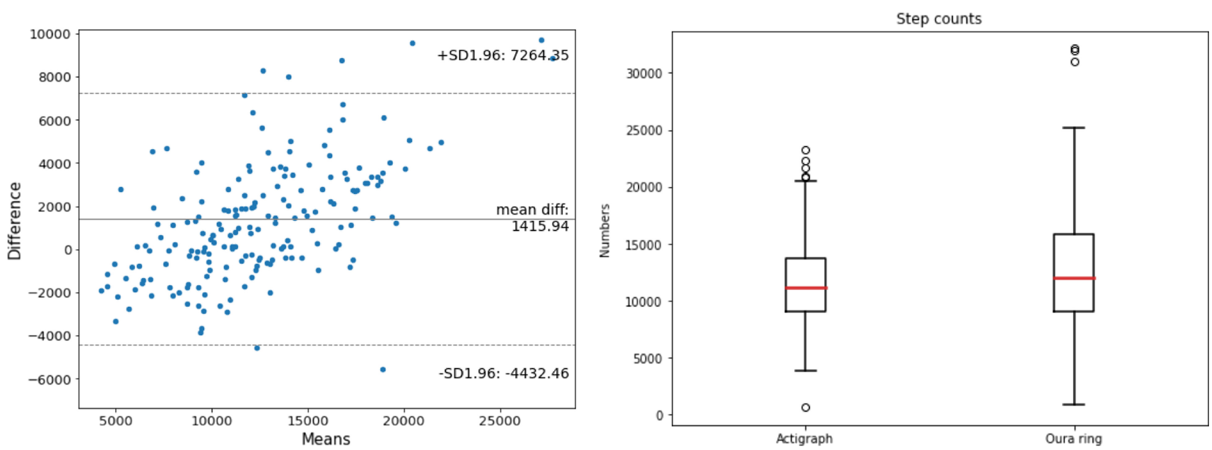


**FIGURE 1.** Bland-Altman plots and the box-plot figure of daily step counts measured by the Oura smart ring and the ActiGraph accelerometer.

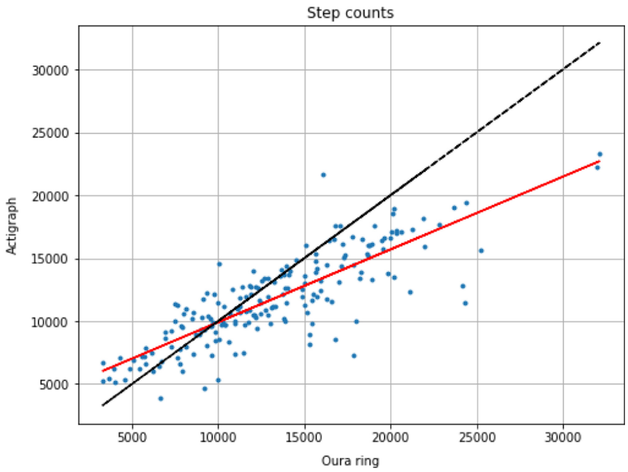


**FIGURE 2.** The scatterplots and regression analysis of daily step counts collected with the ActiGraph and the Oura ring. The regression and ideal lines (ie, $x = y$) are shown in red and black, respectively.

and the Oura ring was reasonable, but 95% limits of agreement were large showing somewhat low validity of the ring in the individual level. The correlation between the devices, however, was high, indicating that the ring has the ability to show group-level differences in step count.

The estimation of sedentary time provided by the ring could be considered accurate, as it was close to the value of the ActiGraph. However, the wrist-worn ActiGraph may underestimate daily sedentary time compared with posture-based estimates of the accelerometer, which is worn on the thigh.[28,29] In the future, the Oura ring should also be validated against a more accurate posture-based method, such as a thigh-worn accelerometer.

The free-living context seems to provide an additional challenge to the accuracy of activity trackers. Many trackers have shown good validity in treadmill tests but are more biased in free-living conditions.[13] Validation studies with different trackers in normal daily life are needed because choosing a device based on validity in controlled settings does not guarantee validity in a free-living context. Previous papers have found the Oura smart ring to be a valid measure for sleep time[17] and for heart rate[30] in a free-living context. Furthermore, the validity of Oura smart ring should be developed as finger-worn activity trackers are light, easy to use, and appealing to users.[8,31] More validation studies are also needed to support the development of new activity trackers.

The results of this study clearly demonstrate the need to carefully consider the characteristics of an activity tracker when used for research purposes as well as in healthcare settings, for example, in nursing interventions.[32] If a tracker is, for example, used as an intervention instrument to support physical activity, it is essential that the measures provided by the device are valid and reliable. Dozens of low-cost wearable activity trackers are commercially available, with large variations in validity; thus, it is not easy to identify the best possible option.[33] The choice of a wearable device depends also on which component of physical activity is of interest.[34]

The results of this study also have implications for nursing as nurses working in different fields of healthcare are in a key position to support their patients being physically active.[35] Increasing physical activity may be an important part of care, for example, in many chronic conditions. Nurses might benefit from understanding the level of validity of activity trackers because they are increasingly popular but still underutilized in nursing.[5] It is notable that in clinical healthcare settings, contrary to research purposes, the accuracy of the device cannot be the only criterion when weighing up the alternatives. Most importantly, the patients or clients need to find the device appealing and easy to use in their normal daily life.[34] Further, if the device is able to show the progress in

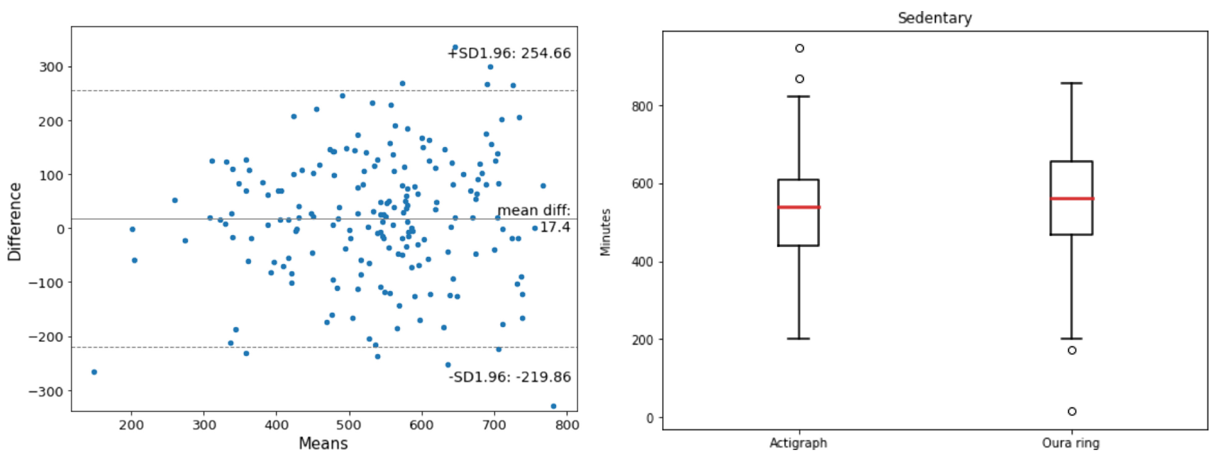


**FIGURE 3.** Bland-Altman plots and the box-plot figure of daily sedentary time measured by the Oura smart ring and the ActiGraph accelerometer.

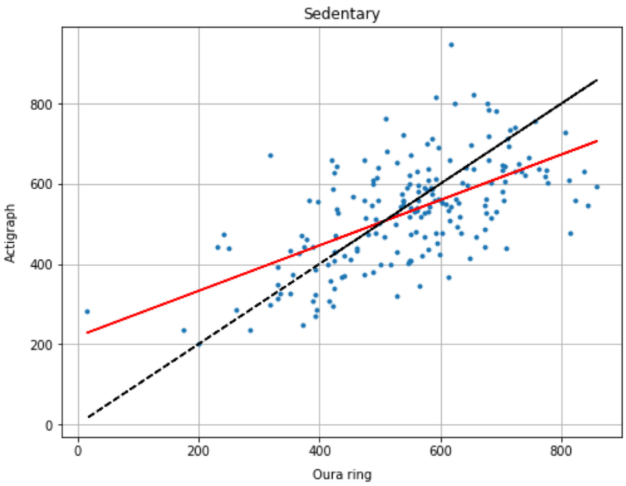

**FIGURE 4.** The scatterplots and regression analysis of daily sedentary time collected with the ActiGraph and the Oura ring. The regression and ideal lines (ie, $x = y$) are shown in red and black, respectively.

physical activity and, by implication, to support the patient to stay active,[6] the exact accuracy of the device might be considered secondary. Individuals wearing activity trackers may be more health aware; thus, nurses working with patients with such trackers may use it as a change agent to support the demanding process of behavioral change.[5,36]

The participants of this study were limited to healthy adults; however, their body mass index and level of physical activity varied, providing quite a diverse sample. A relatively small convenience sample limits the generalizability of the results. A strength of this study was that both the devices were worn on the same hand because estimates of physical activity have been reported to differ between dominant and non-dominant hands. Both devices were placed on the non-dominant hand, which should improve the validity of the measures.[37] However, it has also been suggested that there might not be a significant difference between dominant and non-dominant hands.[38] Each participant used the devices for a week in normal daily life; thus, the amount of data was adequate for the analyses. We were also able to exclude the days when the wear time of the smart ring and the ActiGraph differed more than 10 minutes to minimize the effects of differences in wear or sleep time estimated by the devices.

## CONCLUSION

The Oura smart ring overestimated the step count compared with the wrist-worn ActiGraph accelerometer. The Oura ring showed more accuracy in measuring sedentary time. More research is, however, needed to confirm the validity of the device, as manufacturers continuously develop more sophisticated versions. The Oura smart ring cannot be unambiguously recommended to replace the ActiGraph accelerometer in measuring step count or sedentary time; however, the accuracy of the device cannot be the only criterion when choosing a wearable device for long-term use in normal daily life. Nurses might find these results beneficial while supporting their patients to be physically active.

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