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ORIGINAL ARTICLE

COMPARISON OF WEARABLE ACCELEROMETER AND FOREARM-ATTACHED ACTIVITY PATCH FOR MONITORING PHYSICAL ACTIVITY IN BARIATRIC PATIENTS

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Introduction: Standard, wearable devices for measuring physical activity can be removed by the patient. Therefore, there is concern about the reliability of the results obtained. This study compares selected physical activity measurements obtained with a wearable device to those obtained with an activity patch permanently attached to the patient's forearm (for the duration of a single week only), providing continuous measurement.

Methods: Physical activity was measured simultaneously with both devices in a group of 14 morbidly obese patients over a period of one week: one month before insertion of intragastric balloon (IGB) and one month after its removal. Selected measures (covered distance and energy expenditure during physical activity) were compared both cross-sectionally and in terms of changes over course of the IGB treatment.

Results: The covered distance measurements obtained using both devices were correlated both before IGB placement and after IGB ($r>0.606$, $p<0.024$). Similarly, the increases in distance traveled measurements obtained with both devices were correlated ($r=0.76$, $p=0.04$). The obtained measurements of energy expenditure during physical activity correlated only after IGB removal ($r=0.600$, $p=0.012$).

Conclusion: The results confirm that in large cohorts, measurements of physical activity obtained with wearable devices are comparable to those obtained with activity patches. However, the possibility remains that in individual cases the measurement may differ due to patient non-compliance.

Keywords: physical activity, wearable device, activity patch, obesity, intragastric balloon

Fig.s: 8 • **Table:** 1 • **References:** 32 • **Full-text PDF:** http://www.pjambp.com • **Copyright** © 2023 Polish Aviation Medicine Society, ul. Krasińskiego 54/56, 01-755 Warsaw, license WIML • **Indexation:** Index Copernicus, Polish Ministry of Science and Higher Education

INTRODUCTION

In addition to facilitating everyday life, civilizational development has also brought about a number of negative consequences, including poor eating habits and a concomitant reduction in physical activity. A study published by Statistics Poland [11] on the participation of Poles in sports and recreation revealed that between 1 October 2020 and 30 September 2021, only 38.8% of Poles (36.7% of women and 41.0% of men) participated in sports or physical recreation. The Polish population engaged in physical activity mainly for pleasure and entertainment. The most common form of sports and recreation was cycling. Compared to the previous edition of the survey, the number of physically active people decreased by 7.6%. Given the gravity of the problem, it is essential to adopt and implement effective strategies to promote participation in physical activity (PA) among overweight people.

Physical activity and weight loss is a particularly important goal in the prevention and treatment of overweight and obesity, including morbid obesity [7]. Intentional weight loss can lead to a decrease in clinical symptoms, a reduction in medication use, and a lower risk of mortality [2]. Considering that daily physical activity should be encouraged for obese individuals, it is advisable to start with exercise sessions of 15 minutes, gradually increasing their duration [32].

In general, the results suggest that the use of different types of technology for self-monitoring of diet, physical activity, and body mass is effective in promoting weight loss in overweight people [26]. Approximately half of interventions (47%) that included some type of technology helped participants to achieve significant weight loss compared to the control groups. Raaijmakers et al. observed that 54% of the technology-based interventions significantly helped participants lose weight compared to those without any intervention [23]. Similarly, Allen et al. reported that in 53% of the studies analyzed, statistically significant weight loss was observed in the intervention group relative to the control group [1].

A systematic review ervealed that wearable digital technology, such as AiperMotion (Aipermon GmbH & Co, Germany), has a positive effect on obese patients with diabetes [3,15]. Its main impact on patients is thought to be greater motivation to alter their activity behavior, increase physical activity and by reinforcing self-monitoring. A 2011 German study reported that after 6 months of wearing such a device, the intervention group of obese patients with diabetes had a greater mean weight loss and greater reduction in glycated hemoglobin (HbA1c) compared to the control group [15].

A review of 29 randomized trials [30] of the treatment of obesity through increased physical activity, a low-calorie diet, or a combination of the two, revealed that the greatest weight loss was observed when a rational diet with energy restriction and increased physical activity were combined, taking into account four aspects: frequency, intensity, duration and type of exercise.

Methods that allow objective assessment of physical activity include those that measure energy expenditure, physiological parameters, those that use motion sensors those that use more than one type of measurement [5,14].

Standard wearable devices for measuring physical activity can be removed by the patient at will, e.g. to take a shower, go to sleep etc. Sometimes the patient does not put the device back on after these events. Therefore, important events may be missed, rendering the entire measurement unreliable. The authors' have recently published data on the improvements in physical activity induced by IGB treatment in 14 morbidly obese patients over eight months [8]. Parameters describing physical activity were continuously monitored with an activity patch worn on the skin over one week's period twice: before the intragastric balloon (IGB) placement and after its removal. The patients were also asked to simultaneously use wearable devices for the same period of time. This paper features a comparison of selected measurements obtained with a wearable device (AiperMotion 500; can be attached to the belt by the user) with similar metrics continuous recorded with an activity patch (Metria) that was permanently attached to the patients' forearm for a period of one week (same duration as the wearable device was supposed to be worn). To the best of the authors' knowledge, the Metria device has not previously been used to monitor physical activity in morbidly obese patients. It is a disposable device, which significantly increases the cost of monitoring patient physical activity. The hypothesis of the existence of statistically significant correlation between 1) distance covered (Metria) and number of steps (AiperMotion) and 2) energy expenditure during physical activity (Metria) and measured active energy expenditure (Aiper) was tested.

Tab. 1. The respective demographic and medical parameters for the patients before IGB insertion, after IGB removal, and over the six months of IGB treatment.

	N	Age	Sex [males]	Type 2 diabetes	Weight [kg]	BMI [kg/m^2]
Before IGB Insertion	12	42.3±12.5	3	6	146±25	51.9±7.1
In-between	6	38.7±11.0	2	0	30.6±9.0	54.2±6.6
After IGB Removal	14	44±11	7	8	125±19	42.1±6.3

MATERIALS AND METHODS

Study participants

Twenty-eight patients took part in a neuroimaging study evaluating functional and structural brain changes associated with IGB-induced weight loss [9,10]. Before IGB insertion, 20 correct physical activity measurements were obtained using an activity patch permanently attached to the skin and only 12 measurements using a wearable device. After IGB removal, 18 and 14 correct measurements were obtained with the respective devices. Of those, only six patients had all measurements taken prior to IGB placement and after IGB removal. The respective demographic and medical parameters for the patients before IGB insertion, after IGB removal, and over the eight months of IGB treatment are presented in Table 1. The patients with all measurements lost on average 11.5±2.6 BMI (Body Mass Index) units during the IGB treatment.

All participants gave written informed consent to all procedures prior to the study. All procedures were approved by the Institutional Review Board of the Military Institute of Aviation Medicine in Warsaw, Poland and were performed in line with the ethical standards of the Declaration of Helsinki of 1964 and its subsequent amendments or equivalent ethical standards.

Measuring methodology

AiperMotion 500TM accelerometers (Aipermon GmbH & Co KG, Germany, Fig. 1), designed to measure, record, and analyze daily human activity, were also used to assess physical activity levels. The accelerometer detects movement based on accelerations in three axes — length, width and height. The subjects wore accelerometers on the left side of their waist for seven days, excluding nights. After this period, data from the accelerometers were ripped and analyzed using the AiperView 500TM computer software. In addition to results, such as the average distance covered per day and week, the Physical Activity Level (PAL) coefficient was used to assess participants' physical activity levels. Based on the magnitude of the PAL coefficient, the total energy expended per day during physical activity could be determined by multiplying the basal metabolic rate [29]. PAL of less than 1.5 is considered to indicate low physical activity, while PAL of 1.5 – 1.8 indicates a normal level of physical activity (norm). To reduce the risk of developing obesity-related complications, the World Health Organization (WHO) recommends a physical activity level of PAL > 1.8. Above this level, patients will experience effective weight loss and a reduction in the BMI index. The Metria sensor enables continuous monitoring of the following parameters (for a maximum of 7 days): Total Energy Expenditure, Energy Expenditure During Physical Activity, Daily Time Spent on Physical Activity, Number of Steps Taken, Distance Coverd, Rest Time, Sleep Duration, Sleep Quality, Energy Cost of Exercise expressed in MET units, Exercise Intensity (sedentary, light, moderate, vigorous, and very vigorous).

Fig. 1. AiperMotion 500TM device attached to the patient's belt.

Metria IH1 devices (Vandrico, USA, Fig. 2) were used to automatically assess physical activity duration and active energy expenditure over one week. These devices provided continuous monitoring of the relevant parameters. Any detachment from the arm by the patient would be recorded and such data discarded. Active Energy Expenditure was defined as tasks of more than 1.5 METs (1 MET = energy expenditure of a person sitting quietly). Average parameters describing physical activity (see Tab. 3) were calculated only for the days when the device was attached to the patient's skin for entire 24 hours. In the vast majority of patients, the device was worn for five to six days. Although this device has previously been successfully used to assess PA in soldiers during military training, the authors initially had problems with the device detaching from the skin of morbidly obese patients (23 patients were initially enrolled in the study, nine were lost due to this problem). However, it was resolved [8]. Active Energy Expenditure was defined as tasks of more than 1.5 METs .

MET is the ratio of the working metabolic rate relative to the resting metabolic rate. MET enables the measurement of the body's energy expenditure (kcal) and describes the intensity of an exercise or activity. The higher the MET value of a particular activity, the more energy must be expended by the muscles to perform it. 1 MET is an energy expenditure of a person sitting quietly, whereas 4 MET indicates four times the energy expenditure at rest.

Brisk walking at 4 mph: 5 MET; Swimming at a leisurely pace: 6 MET; Bicycling at 12–14 mph: 8 MET; Running (7 mph): 11.5 MET (based on a person weighing 70 kg). Knowing the MET value of an activity helps to calculate the number of calories burnt during a given exercise. The formula is: METs x 3.5 mlO_2/kg/min x body weight kg / 200 = calories burned per minute.

Fig. 2. Metria IH1 device attached to patient's arm.

Statistical analyses

Correlations between these measurements (number of steps, energy expenditure during physical activity, active energy expenditure) both before IGB placement and after IGB removal, as well as correlations between changes in these parameters due to IGB treatment were evaluated using the Pearson product-moment correlation coefficient in the R Project version 1.1.383 (a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org). The results were visually inspected for outliers. P-values of less than 0.05 were considered statistically significant. Fig.s were prepared in Excel 2010.

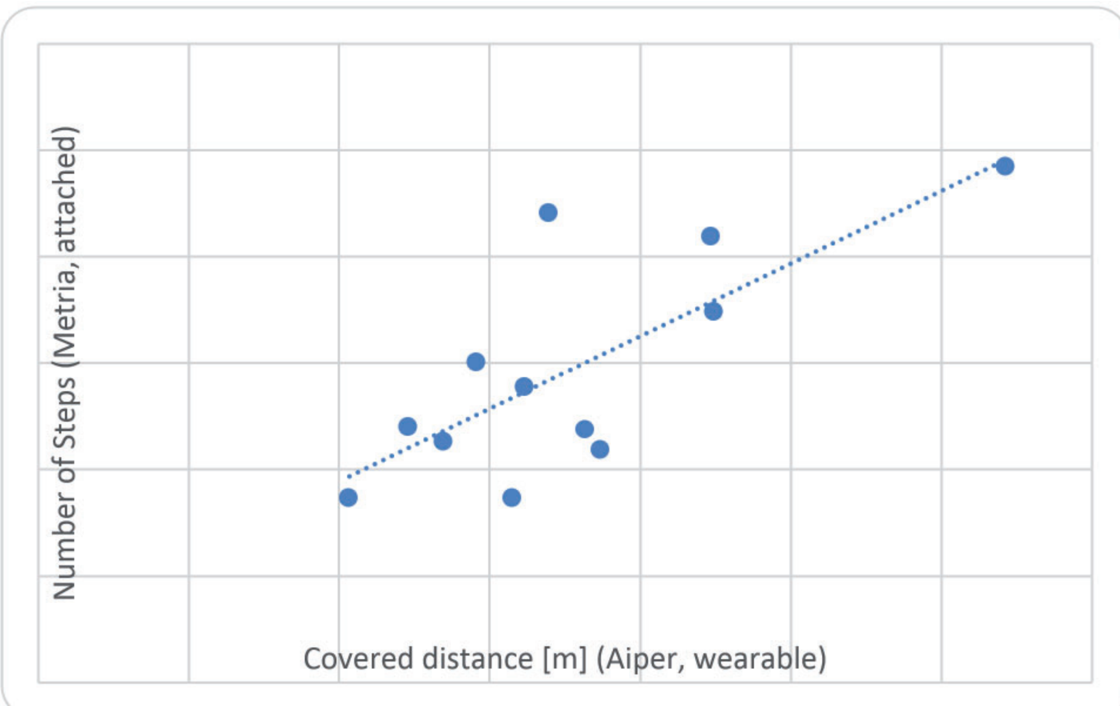

Fig. 3. Relationship between covered distance (AiperMotion) and number of steps (Metria) before insertion of the IGB.

RESULTS

Distance covered was significantly correlated with number of steps (r=0.754, t=3.629, df=10, p=0.002, Fig. 3), whereas energy expenditure during physical activity and measured active energy expenditure were not correlated (r=0.320, p=0.32, Fig. 4).

After outlier removal, distance covered was significantly correlated with number of steps

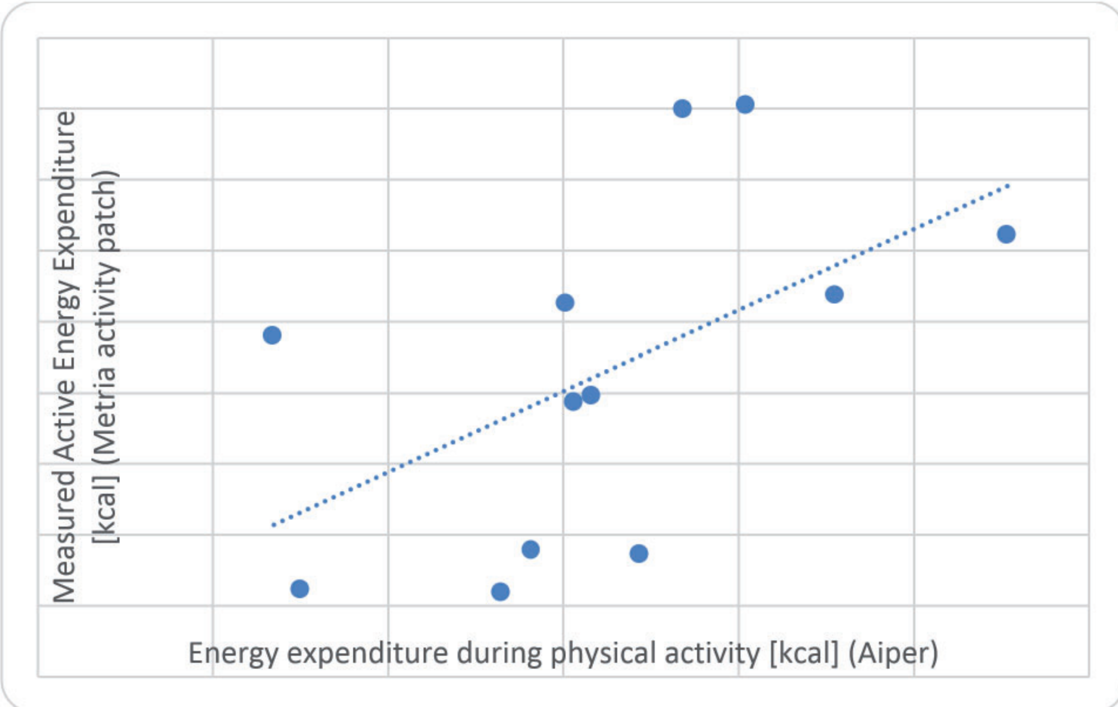

Fig. 4. Relationship between energy expenditure during physical activity (Aiper) and measured active energy expenditure (Metria) before insertion of the IGB. No correlation is observed.

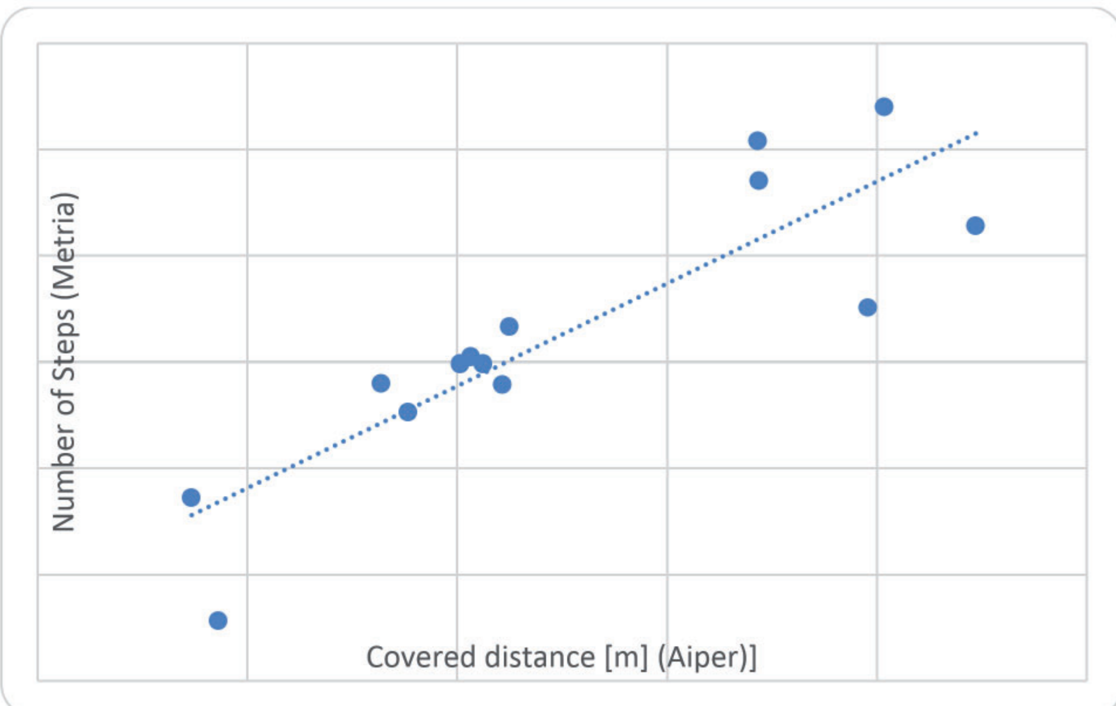

Fig. 5. Relationship between covered distance (Aiper) and number of steps (Metria) after removal of the IGB.

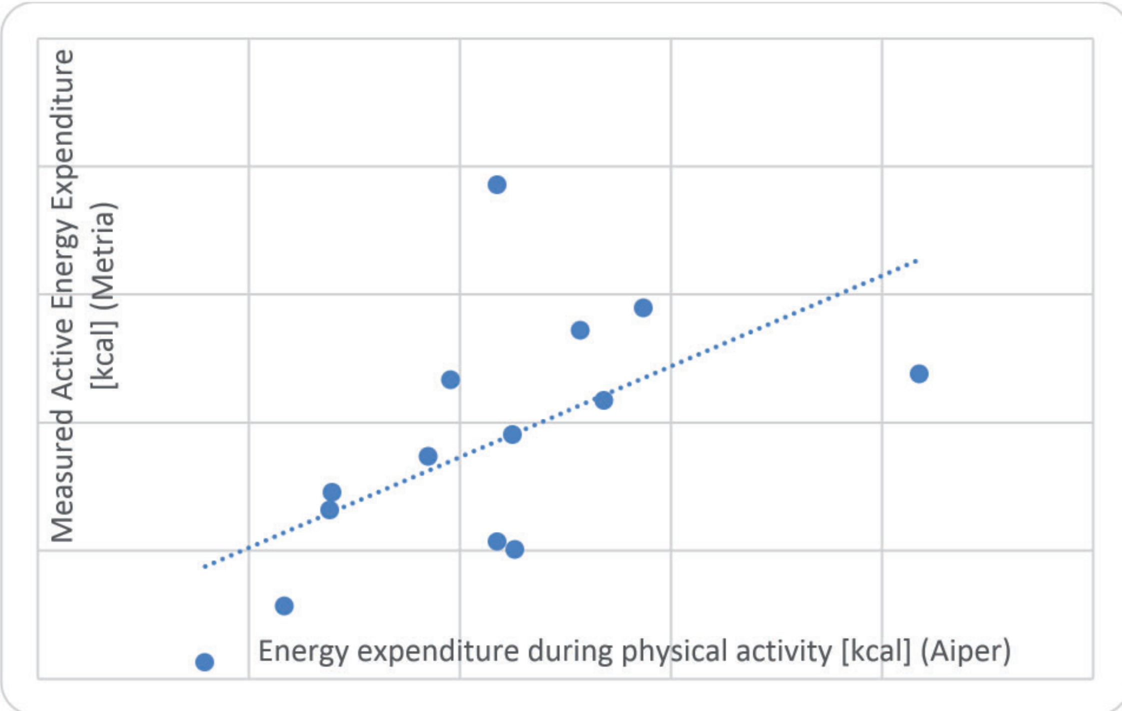

Fig. 6. Relationship between energy expenditure during physical activity (Aiper) and measured active energy expenditure (Metria) after IGB removal.

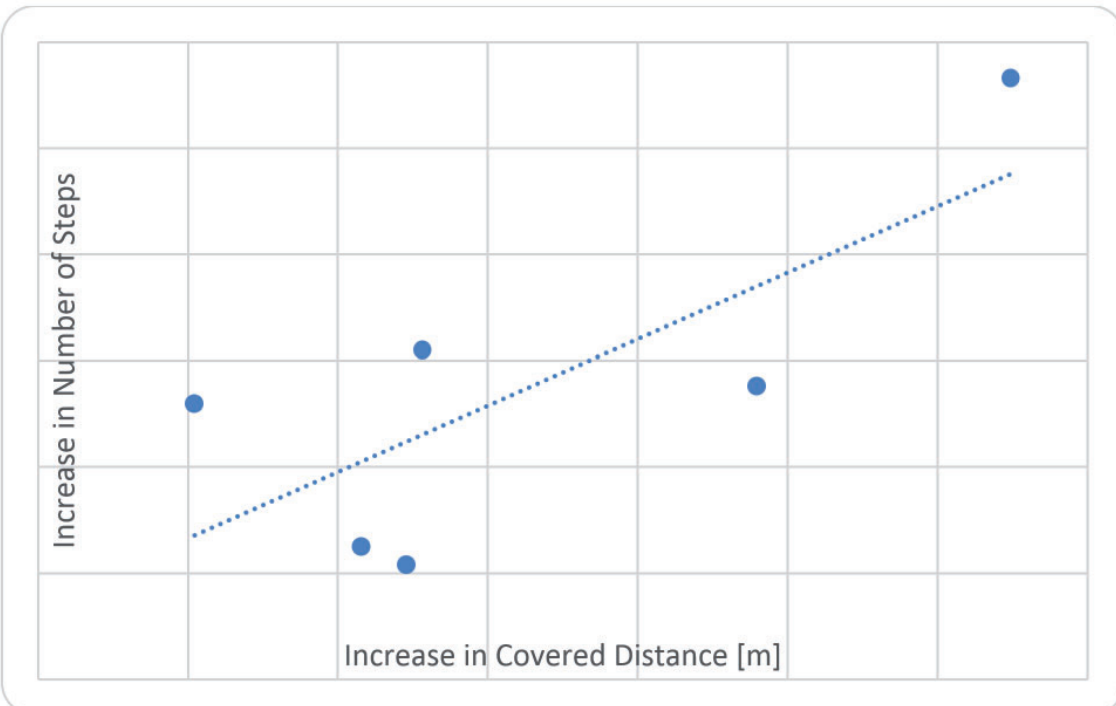

Fig. 7. Relationship between covered distance (Aiper) and number of steps (Metria) during IGB treatment.

(r=0.606, t=2.283, df=9, p=0.024, Fig. 3), whereas energy expenditure during physical activity and measured active energy expenditure were not correlated (r=0.14, p=0.34, Fig. 4).

Similarly, after IGB removal, covered distance was significantly related to number of steps (r=0.870, t=6.127, df=12, p<0.001, Fig. 5). However, in this case energy expenditure during physical activity and measured active energy expenditure

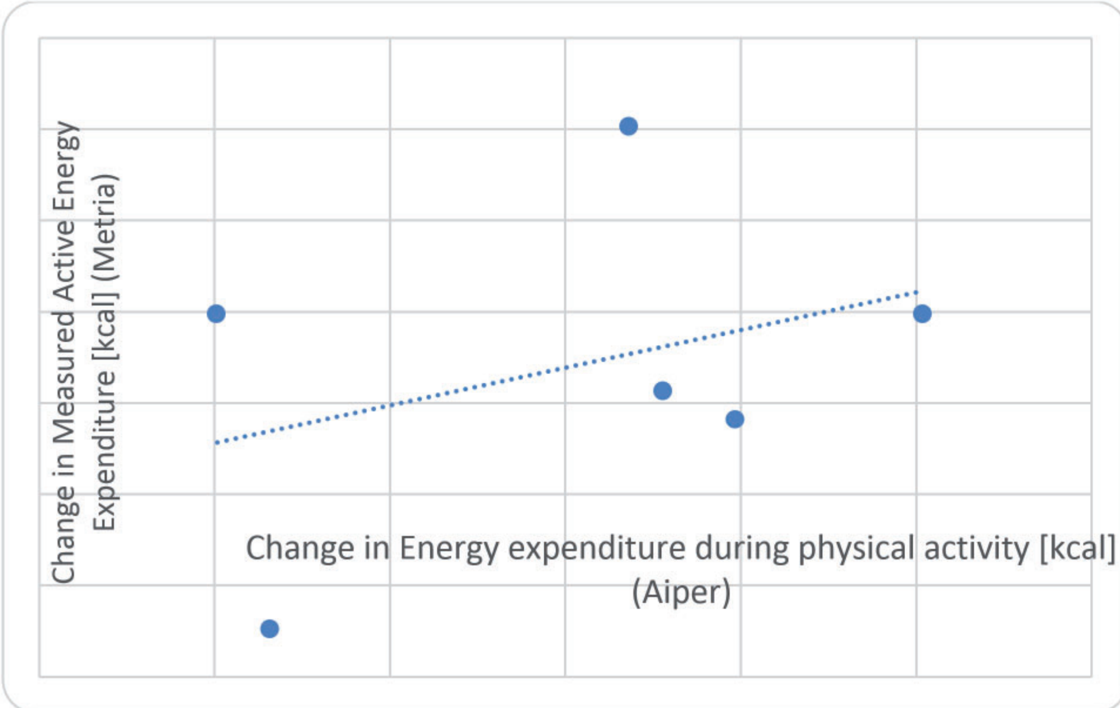

Fig. 8. Relationship between energy expenditure during physical activity (AiperMotion) and measured active energy expenditure (Metria) during IGB treatment.

were significantly correlated (r=0.600, t=2.596, df=12, p=0.012, Fig. 6).

Throughout the treatment, changes in distance covered were significantly correlated to changes in the number of steps (r=0.757, t=2.32, df=4, p=0.041, Fig. 7), whereas changes in expenditure during physical activity were not significantly correlated to changes in measured active energy expenditure (r=0.358, t=0.767, df=4, p=0.25, Fig. 8).

DISCUSSION

In the era of digital healthcare, self-control weareable divices are a developing area of medicine and research. Weareable sensors enable consistent and remote monitoring and reporting of activity-related vital signs of patients with chronic illnesses (e.g., [17]).

In evaluating the accuracy of research wearable sensors, the monitors have mostly been used on healthy participants and have shown similarities in estimating physical activity. Several studies revealed significant effects of accelerometer intervention for PA on weight loss [12,24] and body mass index (BMI) [16]. Numerous studies compared wearable devices (accelerometers, pedometers) with standard clinical treatments (self-monitored physical activity with questionnaires or internet-based tools, personal support in exercise and dietary restriction). To the authors' knowledge, this is one of the first studies in obese patients undergoing IGB treatment to compare an activity sensor worn on the skin of the arm with a 3-axis accelerometer worn on the hip/waist.

The authors conducted a continuous recording for 7 consecutive days in order to test whether two devices could be used interchangeably to monitor bariatric patients: an activity patch permanently attached to the skin of the arm (Metria) and a wearable accelerometer worn on the hip that could be removed by the patient at will (AiperMotion 500). The authors measured distance covered and energy expenditure, key components that help reduce body mass or regulate body composition, an important goal for overweight and obese individuals. This study revealed that covered distance and energy expenditure during physical activity were generally correlated between an arm-worn sensor (Metria) and a hip-worn device (AiperMotion 500) (Fig 3. And Fig.5.). The distance covered measurements hsowed a significantly better correlation between these devices. The above study results suggest that activity patches attached to the arm (Metria) are a suitable and an acceptable alternative to hip/waist wearable accelerometers (AiperMotion 500) for physical activity monitoring.

These results are consistent with previous studies. In Ireland, McDevitt et al. [19] found similarities in physical activity parameters between the two wearable devices. The authors compared wrist accelerometers which are desirable in clinical research as a device for 24-hour activity monitoring of PA and sleep. The study analyzed data obtained from the Actiwatch 2 and Verisense devices over the 2 days from 15 healthy students. The overall activity patterns for the FL Free Living and Supervised Protocol –treadmill walking at a variable pace observed between the two wrist monitors appear to be fairly similar. Meanwhile, motion monitoring results were also highly correlated.

The authors observed concordance between Verisense and Actiwatch 2, there was moderate agreement in the determination of values, sensitivity, specificity and accuracy in detecting three PA levels (sedentary, light and MVPA – Mmoderate to Vigorous Physical Activity). In the Free Living study, physical activity measurements taken using the Actiwatch 2 and Verisense sensors were highly correlated for sedentary activity (0.2±0.05) and moderately correlated for light activity (0.42±0.06) and MVPA (0.52±0.09). Under Supervised Protocol conditions, physical activity for the two sensors were moderately correlated for MVPA (0.49±0.13), but, poorly correlated for sedentary (0.36±0.016) and light activity.

In contrast, previous studies reported less agreement. In the Cellini's study [4], two wearable monitors were attached to each healthy participant (n=30): on the wrist and the hip for 3 consecutive days. Correlation coefficients showed very low agreement between the two wearable monitors for sedentary, light activity and MVPA. Also a high degree of error was observed for physical activity parameters for the wrist monitor, especially for light activity and MVPA, whereas sedentary time showed moderate degree of error. In general, among the three physical activity levels, the MVPA showed the lowest degree of error for the wrist accelerometer compared to the hip-worn monitor [4].

However, when the results are analyzed in terms of activity energy expenditure AEE (kcal) the observations of other authors are reasonably consistent with the authors' observations. Esliger et al. reported that 3-axis accelerometer worn on the waist/hip showed an almost similar correlation with energy expenditure as the device worn on the wrist [6]. Likewise, Cellini's study showed a moderate correlational agreement in the measurement of energy expenditure when comparing the two wearable monitors worn on wrist and hip for over 72 hours.

However, the lack of a high significant correlation observed for energy expenditure in our study may be due to the unintentional increase in the device non-wear time (AiperMotion) which resulted in the loss of some of data. Of concern is the lower number of measurements obtained with the wearable device in general, indicating patient noncompliance. This occurred when the participant forgot to put the device back on after a bath or a night's sleep.

In this study, the results with regarding physical activity behavior (distance covered and energy expenditure) generally correlated between two monitors (AiperMotion 500 vs Metria) most likely due to one main reasons – the device's location. A number of previous studies have suggested using sensors worn on the waist rather than the wrist [28,31]. Other studies have shown that hip-worn monitors yield better results than wrist-worn monitors [27]. Also, physical activity parameters are more accurate when an accelerometer is worn on the hip than on the wrist [20]. With this in mind, the authors placed accelerometers on the waist/hip and patch sensors on the arm instead of the wrist.

Moreover, being limited to a specific research group of individuals suffering from obesity could restrict the effectiveness of automatic medical device in other populations. Another limitation of the study is that the differences between the measured variables may reflect differences in the applied mathematical models used to calculate physical activity.

It is worth pointing out that activity patches (Metria) allowed for uninterrupted monitoring 24 hours a day, whereas wearable devices (Aiper) requires the experimenter to believe that the patient's measurements were correctly recorded and that no important events were missed.

The continuous attachment to the skin facilitates monitoring, especially of the elderly or patients with mental illness, depression or memory disorders. In this particular group, there may be a higher risk of forgetting to reattach the device correctly. Therefore applied measures should be taken to assure patient compliance, taking into account their behavior and daily/nightly activity patterns.

Important aspects of assessing physical activity are that the current reliance on self-reporting is vulnerable to missing information from a patient, including information on activity intensity, distance covered and time spent being sedentary [21]. Individuals are poor in identifying light and intermittent short-term bursts of vigorous physical activity, thus the use of questionnaire-based approaches with self-reported activity levels may be considered inaccurate [18].

Another aspect is that for working people, wearing digital monitors is more accessible and convenient than in-person visits to health clinics for traditional treatments (face-to-face group and individual sessions), as the data can be delivered remotely as well as analyzed in real time.

CONCLUSIONS

The results obtained confirm that in large cohorts, the physical activity measurements recorded using wearable devices are comparable to those recorded with activity patches. Moreover, these two devices could be used interchangeably to monitor patients with chronic diseases. Due to their ease of use and the high prevalence in society, they could be implemented to effective strategies to promote physical activity behavior in obese patients [25]. However, there is still a possibility that in individual cases, the readings may differ due to patient noncompliance.

The use of wearable technology in the clinical therapy continues to grow, however, sensor algorithms may hinder their research applications. Any initiative to develop algorithms and software for such medical devices can serve to improve patient health care [22]. Therefore, further studies on physical activity levels in other populations including overweight participants in promoting healthy behaviors are needed.

Existing evidence has also shown that the effectiveness of a single accelerometer or activity sensor technology in overweight or obese individuals can be improved by using multimodal approaches, such as combining them with individualized interventions, personal trainers or informational messages [13].

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: The authors declare that they have no conflict of interest.

Statement of Informed: Consent Informed consent was obtained from all individual participants included in the study.

Ethical Approval: All procedures were in accordance with the ethical standards of the institutional research committee of the Military Institute of Aviation Medicine School and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

AUTHORS' DECLARATION:

Study Design: Agata Gaździńska, Stefan Gaździński. **Data Collection:** Agata Gaździńska. **Manuscript preparation:** Agata Gaździńska, Stefan Gaździński. Anna Przewodzka. The Authors declare that there is no conflict of interest.

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