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‘Tracking Together’—Simultaneous Use of Human and Dog Activity Trackers: Results from a Factorial, Randomized Controlled Trial

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Abstract **Objectives:** Dog-walkers are more likely to achieve moderate-intensity physical activity. While human activity trackers have been shown to increase physical activity intensity, dog activity trackers may increase owner’s awareness of their dog’s physical activity. This trial examined the effects of simultaneous use of activity trackers by humans and their dogs. **Methods:** In this 2x2 factorial randomized trial (N=85), each group consisted of dog-human duos, in which both human and dog, human only, dog only, or none were wearing an activity tracker for 8 weeks. ANCOVA tests compared ActiGraph accelerometer data across groups in week-1 and week-10. Chi-square tests compared human activity tracker data during eight weeks. **Results:** Based on accelerometer data in week-1 and week-10, group assignment had no statistically significant effect on sedentary, light, moderate, or vigorous activity, but between-group difference in moderate activity was marginally significant. However, activity tracker data during the 8-week trial period demonstrated that humans in the group that used both human and dog activity trackers compared to humans in the group that used only human activity trackers completed more light physical activity. There were no significant changes in body composition. **Conclusions:** While simultaneous use of activity trackers by dog-human duos was associated with increased light physical activity among humans over eight weeks, a longer trial with a larger sample size may establish behavioral differences between groups. Simultaneous use may also increase dog-engaged physical activities and sustained use of trackers. Future studies should explore interventions that use paired activity trackers for improving human physical activity.

Keywords: *Human activity trackers, Canine activity trackers, Dog walking, Physical activity*

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1. Introduction

Over 42% percent of U.S. adults ages 20 and older are categorized as obese (BMI > 30.0), with an additional 31.1% of the population being categorized as overweight (BMI 25.0-29.9).[1] Companion animals have been shown to suffer from a high prevalence of obesity as well, with an estimated 19.6% being categorized as obese and an additional 36.4% being categorized as overweight in 2017. [2] Particularly, 59% of dogs were classified as overweight or obese in 2022. Further, obesity and overweight status amongst dog owners is positively correlated with obesity and overweight status of their companion dogs. Interestingly, obesity and overweight status in dog owners is the greatest predictor of a companion dog’s weight with dogs being at three times greater risk of being obese or overweight when their owners are obese or overweight compared to owners of a healthy weight. [3] The second strongest predictor of companion dog’s weight is the physical inactivity of dog owners, with dogs being two times more likely to be obese or overweight when their owners are sedentary compared to active. [3]

In the meantime, exercise recommendations for adults are to spend a minimum of 150-300 minutes per week participating in moderate intensity exercise, or a minimum of 75-150 minutes per week participating in vigorous intensity exercise. [4] Importantly, individuals who walk dogs have been shown to be 2.5 times more likely to meet the recommendation of moderate intensity exercise, compared to those who do not walk dogs. [5] This evidence suggest that dog walking can have a significant impact on the physical activity level of the population because 44.5% of U.S. households owned a dog in 2022 following an increase by 6.1% between 2016 and 2022, whereas the estimated population of pet dogs was between 83.7–88.9 million in 2020. [6]

A meta-analysis has demonstrated activity trackers are a reliable way of promoting physical activity in humans by increasing average daily steps, total energy expended, and time engaging in moderate or vigorous exercise; meanwhile, no effect has been shown on total sedentary time. [7] Activity trackers have been established as a valid mechanism for measuring the aforementioned variables in dogs, even though the relationship between activity trackers and exercise in dogs has not been completely elucidated. [8] While activity trackers are established as useful in initiating exercise, long-term data has not found activity trackers lead to sustained increases in exercise. [9] The use of activity trackers in dogs has been effective in heightening the dog owner's awareness of the dog's physical well-being. [10] By increasing awareness of both the owner's and the dog's physical activity, it is reasonable to expect a greater increase in physical activity when both a dog owner and dog have activity trackers compared to when only either owner or dog, or when neither are wearing activity trackers.

The purpose of this randomized controlled trial is to measure behavior changes in light, moderate, and vigorous physical activities and sedentary behaviors, based on the participants group designation; owner only wearing an activity tracker, dog only wearing an activity tracker, both dog and owner wearing activity trackers, neither dog nor owner wearing activity trackers.

2. Methods

Study Population

Details of the study design, recruitment, and data collection can be found in the complete protocol of this trial which has been published previously. [11] The study was conducted in a U.S. Midwestern college town with a racial composition of 83.0% white alone, a median age of 23.4 years, and a median household income of $42,000. Eligibility criteria for human participants were age between 25 and 65 years, owning a dog, and owning a Fitbit- and Whistle-compatible smartphone. The targeted sample size was 80. To increase the accuracy of this study, following exclusion criteria were used: people who are participating in another study that affects their physical activity or interaction with dog, those who are already wearing activity trackers, and those who are caring for a dog but are not the owner of the dog. This clinical trial was approved by both Institutional Review Board (IRB) and Institutional Animal Care and Use Committees (IACUC). Dogs with physical activity and functional limitations were excluded.

Study Design

The study involved a randomized controlled trial with a two-by-two factorial design based on use of dog or human activity trackers for eight weeks (Figure 1). The Fitbit Charge-3 was used for tracking human physical activity. The dog activity tracker "Whistle Fit" was used for tracking dog activity. Each group consisted of dog–human duos, in which none, either, or both was/were wearing an activity tracker for eight weeks. The four groups were: 1) *"Fitbit Group"* in which the dog owners wore a Fitbit during the observation, 2) *"Whistle Group"* in which the participants' dog wore a Whistle during the observation, 3) *"Fitbit-Whistle Group"* in which the dog-owners wore a Fitbit and their dog also wore a Whistle, 4) *"True Control Group"* in which neither the participant nor their dog wore any activity tracking device. This trial was unique in the sense that it was observational and involved two species. The study is considered observational because the researchers did not ask study participants to change their physical activity level or any other behavior, rather participants were just asked to use the activity trackers and any behavioral changes associated with participants' activity tracker use was observed.

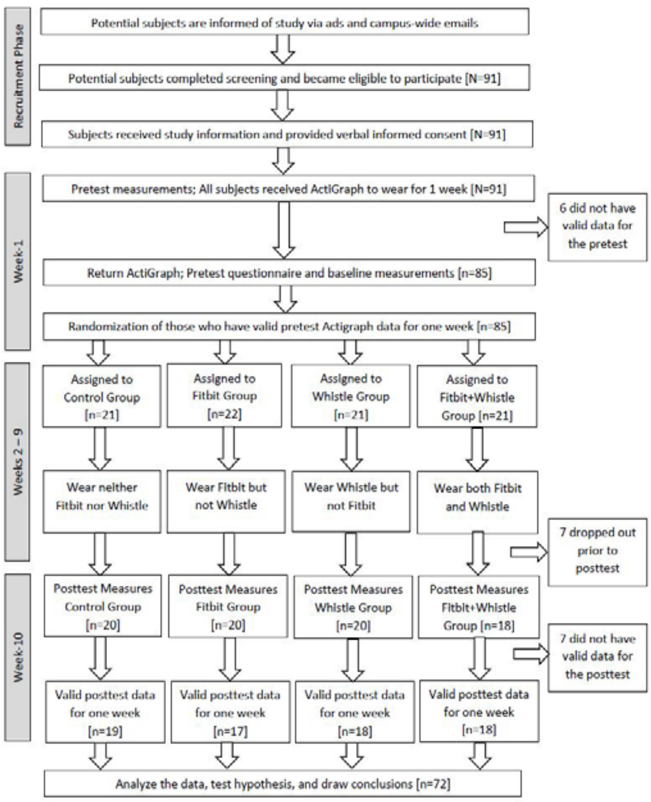

Figure 1. CONSORT Diagram for Factorial Randomized Trial on Use of Human and Dog Activity Trackers

Sampling

This community-based trial used nonprobability (convenience) sampling to draw a sample from the town's dog-owners who are interested in participating in the study. Sample size estimations based on prior studies [12] revealed that a sample of 20 per group (80 total) provide 80% power to detect a “medium/large” effect size (Cohen’s f = 0.32) for main effects or the interaction. The study used a staggered recruitment to recruit participants in small batches. Physical and digital recruitment flyers were distributed through various channels, such as notice boards on campus, animal shelters, and social media.

Data Collection

The data were collected during December 2020 through April 2022 (see the protocol paper for more details). [11] Outcomes were measured both continuously and at two time points under free-living conditions– week-1 (baseline) and week-10 (end-of-trial). The observation was conducted for 10 weeks for each participant and their dog. The dog owners in the Fitbit group and in the Fitbit-Whistle group wore a Fitbit device for eight weeks (second week through ninth week). The dogs in the Whistle group and in the Fitbit-Whistle group wore a Whistle device during the same period. Dog-owners and dogs in the true control group did not wear any activity tracker. To quantify and categorize (i.e., sedentary, light, moderate, and vigorous) human physical activity— as well as to obtain the step count (per hour), a research-grade accelerometer, ActiGraph GT3X, was used. All participants (regardless of group assignment) were asked to wear an ActiGraph device at least 10 hours per day during the first week (i.e., before randomization) and the tenth week (i.e., before exiting the study). Measurements of 30Hz with an epoch of 60 seconds was used to capture physical activity counts for 7 days in each week. The ActiGraph software, ActiLife, was then used to convert activity counts into minutes spent in different physical activity intensities [13] (Table 1).

During the second through ninth week, data from Fitbit activity trackers were collected remotely from the two groups that wore them. Fitbit measured light and vigorous activity as well as sedentary minutes. Additional objective measures for humans included height, weight, and bioelectrical impedance analysis (BIA; Tanita DC-430U) which were obtained in a laboratory setting during the baseline (week-1) and exit (week-10). Height and weight were measured using a stadiometer and digital scale. In BIA, changes from week-1 to week-10 were calculated for body weight (kg), fat (kg), muscle (kg), visceral fat (kg), BMI (kg/m^2), and basal metabolic rate [BMR] (kcal).

Subjective measures were obtained using a Qualtrics survey. International Physical Activity Questionnaire (IPAQ) was used to measure human physical activity. [14] Theory of reasoned action approach (RAA) was utilized to explore determinants and beliefs with regard to dog-walking behavior. [15] Findings from behavioral questionnaires are forthcoming. Furthermore, canine physical activity was measured using a questionnaire, developed specifically for this study but consisted of questions derived from validated study instruments. [16] Please see Table 1 for descriptions of the variables of interest in this manuscript.

Statistical Analysis

Data Validation: The study enrolled 91 participants, but 12 were excluded from the analysis due to insufficient wear time (less than four 10-hour days of valid wear time), while 7 more were lost to follow up and were deleted listwise. In summary, 19 participants were excluded from the analysis; 13 of these subjects were randomized and 6 of them dropped out prior to randomization. Of the 13 that were randomized, 5 were in the Fitbit, 3 in the Whistle, 3 in the Fitbit+Whistle, and 2 in the Control (see Figure 1 CONSORT diagram for details).

Table 1. Characteristics of the Variables Measured in the Study

Dependent Variables	Description (Physical Activity)
Average minute difference in sedentary activity between weeks 1 and 10	The difference of the average minutes of participants’ sedentary activity between the first and the tenth week of the observation; The amount of sedentary activity was measured by ActiGraph when participants were in sedentary positions, <100 counts/minute *
Average minute difference in light activity between weeks 1 and 10	The difference of the average minutes of participants’ light physical activity between the first and the tenth week of the observation; The amount of light activity was measured by ActiGraph when participants were doing activities, 100–2019 counts/minute *
Average minute difference in moderate activity between weeks 1 and 10	The difference of the average minutes of participants' moderate activity between the first and the tenth week of the observation; The amount of moderate activity was measured by ActiGraph when participants were doing activities, 2020–5999 counts/minute *
Average minute difference in vigorous activity between weeks 1 and 10	The difference of the average minutes of participants’ vigorous activity between the first and the tenth week of the observation; The amount of vigorous activity was measured by ActiGraph when participants were doing hard exercise, >5999 counts/minute *
Average difference in steps between weeks 1 and 10	The difference of the average steps (per hour) between the first and the tenth week of the observation, measured by ActiGraph.
Average sedentary minutes in the 2–9 weeks	Activity minutes, recorded by Fitbit, in the weeks two through nine in the Fitbit Group and Fitbit-Whistle Group
Average light activity minutes in the weeks 2–9	Light activity minutes, recorded by Fitbit, in the weeks two through nine in the Fitbit Group and Fitbit-Whistle Group
Average vigorous activity minutes in the weeks 2–9	Vigorous activity minutes, recorded by Fitbit, in the weeks two through nine in the Fitbit Group and Fitbit-Whistle Group
Average difference in BIA variables between weeks 1 and 10	Body weight (kg), body fat (kg), muscle (kg), visceral fat (kg), BMI (kg/m2), and basal metabolic rate [BMR] (kcal)
Independent Variable	**Description (Group Membership)**
Group	This categorical variable includes four group levels: Fitbit, Whistle, Fitbit-Whistle, and Control.

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Daily averages from the ActiGraph variables were calculated by dividing the values of corresponding variables by the number of days the participant were wearing the ActiGraph accelerometer. The resulting values were averaged across groups. The same procedure was used to calculate the number of steps per hour of ActiGraph wear time. In visual inspection, the average minute difference in sedentary, moderate, and vigorous activities followed a normal distribution, whereas light activity followed a bimodal distribution. The normality tests were supported by using QQ (quantile-quantile) plots. However, Shapiro-Wilk normality test results identified that the average minute difference in vigorous activity did not follow a normal distribution ($p<0.05$), although the sedentary, light, and moderate activities did follow a normal distribution. According to the Bartlett test of homogeneity of variances, the average minute difference in sedentary, light, and moderate activities showed similar variances in each group, but unequal variances were observed for vigorous activity (i.e., violation of homoscedasticity).

Descriptive and Inferential Statistics: The purpose of the study is to compare how humans' sedentary, light, moderate, and vigorous activities change from before to after humans and/or their dog wear an activity tracking device. If the hypothesis that wearing an activity tracking device positively affects human activity is correct, the average minute difference in sedentary activity is expected to have a negative value, but the average minute difference in light, moderate, and vigorous activity are expected to have positive values. A 2 × 2 factorial analysis of covariance (ANCOVA) was used to compare physical activity across the 4 groups from baseline (week-1) to week-10, using group membership, baseline value of the corresponding activity category, and their interaction as fixed effects. The dependent variable was the average minute difference in sedentary, light, moderate, or vigorous activity or the step count per hour. The first four ANCOVA models include interactions between a predictor and a covariate. The other four ANCOVA models had no interactions. As the parametric tests, such as ANCOVA, could be unreliable due to violations of normality and homoscedasticity assumptions, a permutation test (a non-parametric method) which is known to be robust to violation of the normality and homoscedasticity assumptions was conducted using mean differences to support the results. In the analysis of Fitbit activity tracker data, the Chi-square test compared minutes by group, day of the study (1 through 56), and their interaction.

3. Results

The distribution of 72 participants included in the analysis was: Fitbit=17, Whistle=18, Fitbit-Whistle=18, and control=19. Participants were relatively young and predominantly female. There was no significant difference between the groups in terms of mean age of participants in years (Fitbit=34.9, Whistle=34.1, Fitbit-Whistle=35.6, control=36.4) or the percentage of females in each group (Fitbit=70.6%, Whistle=72.2%, Fitbit-Whistle=94.4%, control=84.2%).

At baseline (first week), all but 1 participant had at least 150 minutes of objectively measured moderate intensity physical activity. The one subject that did not meet physical activity recommendations of 150 minutes of moderate physical activity, had 149 minutes of moderate physical activity and no vigorous physical activity. At baseline, 13 subjects had ≥75 minutes of vigorous physical activity. In the tenth week, 4 participants did not meet physical activity guidelines, which included 1 participant from each group type. These subjects had 119, 61, 129, and 137 minutes of moderate physical activity and no vigorous physical activity; 10 participants had ≥75 minutes of vigorous physical activity. According to BIA measurements obtained in the laboratory, there were no significant changes in body weight (kg), body fat (kg), muscle (kg), visceral fat (kg), BMI (kg/m2), and BMR (kcal) from week 1 to 10.

The ANCOVA models that included interactions found significant effects of baseline activity level on average minute differences in sedentary, moderate, and vigorous activity (Table 2). As well, significant interaction effects of the group assignment and baseline activity level were found on average minute differences in moderate and vigorous activity. While group assignment had no significant effect on any of the activity levels, the average minute difference in moderate activity was marginally significant ($p=0.06$), indicating that a larger sample size and/or a longer trial would likely to be able to detect a significant difference. Similarly, the ANCOVA models that did not include interactions found significant effects of baseline activity level on average minute differences in sedentary and vigorous activity.

Table 2. The Results of ANCOVA Models with interaction

Response Variable		Df.	Sum Sq.	F value	P value
Average minute difference in sedentary activity	(intercept)	1	105.61	5.43	0.0229*
	Group	3	13.42	0.23	0.8751
	Baseline Sedentary	1	100.84	5.18	0.0261*
	Group* Baseline Sedentary	3	15.80	0.27	0.8458
	Residuals	64	1244.43		
Average minute difference in light activity	(intercept)	1	0.47	0.0312	0.8603
	Group	3	34.44	0.76	0.5158
	Baseline Light	1	0.71	0.05	0.8285
	Group* Baseline Light	3	14.70	0.38	0.2550
	Residuals	64	831.80		
Average minute difference in moderate activity	(intercept)	1	18.66	4.62	0.3552*
	Group	3	5.99	0.48	0.0606
	Baseline Moderate	1	12.51	2.99	0.0072*
	Group* Baseline Moderate	3	18.50	1.48	0.0252*
	Residuals	64	267.42		
Average minute difference in vigorous activity	(intercept)	1	0.08	0.92	0.3409
	Group	3	0.21	0.78	0.5095
	Baseline Vigorous	1	10.93	120.29	0.0001*
	Group* Baseline Vigorous	3	1.28	4.69	0.0051*
	Residuals	64	5.82		

Results of the permutation tests that are known to be robust to the assumption violations indicated no significance with p values greater than 0.05. These results supported the same results from the ANCOVA models in the previous analysis.

Similarly, no significant differences were found in terms of step count per hour between groups (Figure 2). However, average steps were significantly higher ($p<0.05$) in the Whistle group without the single outlier in that group, who was traveling during the study intervention.

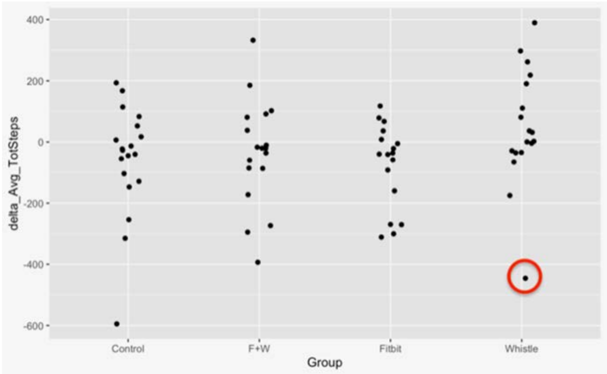

Figure 2. Change in Steps per Hour of ActiGraph Wear Time from Week 1 to 10 Groups

Chi-square test results from the analysis of Fitbit activity tracker data from the Fitbit and Fitbit+Whistle groups for weeks 2 through 9 revealed that minutes of light intensity physical activity significantly differed between the two groups ($\chi2=3.896$; df=1; p=0.048); dog owners in the Fitbit+Whistle group, compared to those in the Fitbit group, completed more light physical activity (Figure 3). There was no significant difference between Fitbit and Fitbit+Whistle groups for sedentary activity; however, there were significant differences by day 1 through 56 (8 weeks) where sedentary minutes decreased over time ($\chi2=75.274$; df=1; p=0.036).

Figure 3. Fitbit Tracker Data from the Fitbit and Fitbit+Whistle Groups for Weeks 2-9

4. Discussion

In this trial, the 8-week group assignment had no statistically significant effect on activity levels (sedentary, light, moderate, and vigorous intensity), based on accelerometer data in weeks 1 and 10. However, the between-group difference in moderate activity was marginally significant, indicating that a larger sample size would likely to be able to detect a significant difference. Most importantly, activity tracker data in weeks 2 through 8 revealed that dog owners in the Fitbit+Whistle group, compared to those in the Fitbit group, completed more light physical activity, whereas sedentary minutes decreased over time in both groups. In summary, this study was unable to reject the null hypothesis, although some secondary outcomes were significant. While a longer trial with a larger sample size may establish noticeable behavioral differences between groups, findings of this study provided insights into physical activity interventions that leverage human-canine interaction as well as directions for future research studies.

Use of activity trackers among humans has created opportunities for behavior change techniques through goal setting, increased self-awareness, and self-monitoring as well as positive reinforcement. [17] Furthermore, with technological advancements, activity trackers have become smaller and user-friendly as well as versatile through integration with portable digital devices (e.g., mobile phones and iPads) to provide more feedback for self-monitoring and behavior change. Simultaneously, technological advancements have created opportunities for researchers and clinicians to access objective data for tracking human physical activity instead of depending on self-reported data. According to a 2019 systematic review, the use of activity trackers has received increased attention from the general population during the last decade and the number of studies that used activity trackers has increased from 8 to199 during the 5 year period between 2013 and 2017. [18] This observational community-based trial adds to the growing body of literature a novel technique of using activity trackers for self-monitoring in the context of human-animal interaction. Moving forward, the technique may have the potential for development as a self-initiated or clinician-guided, community-based intervention using the concepts of goal setting and positive reinforcement.

Perception of pet obesity varies widely across pet owners and veterinary professionals. For example, in contrast with that 56% of dogs are actually either obese or overweight, only 39% of dog owners consider their dog obese or overweight. [2] Regardless, 72% of pet owners and 87% of veterinary professionals recognize pet obesity as a disease, and 46% of pet owners reported that their veterinarian discussed their pet's ideal weight every year. Tracking of dog physical activity, as demonstrated in this study, will have important implications for improving dog physical activity that may involve goal setting and monitoring in both veterinarian-guided and dog owner-initiated interventions for obesity and cardiovascular disease prevention among dogs. Tracking of dog activity has implications beyond dog obesity prevention. Below-normal activity levels among dogs often indicate health concerns, such as sickness, impaired mobility, and pain, [19] whereas above-normal activity levels can imply health problems, such as pruritus. [20] Furthermore, activity level can serve as an indicator of the amount of sleep and rest dogs are getting. [21] Therefore, tracking of dog activity can guide dog owners and veterinarians to identify deviations from normal activity and initiate interventions without unnecessary delay.

On the other hand, this study has important implications for human health as well, because tracking of dog activity may influencee dog owners to increase their own physical activity simultaneously, either intentionally or unintentionally, thereby improving their cardiovascular health, regardless of their weight status. An analysis of national self-report data revealed that adherence to guidelines for aerobic activity was only 65.2% in 2015-2016, whereas sedentary time significantly increased from 5.7 hours/day in 2008 to 6.4 hours/day in 2015-2016. [22] Therefore, motivating dog owners to track their dog's activity may be a promising strategy for increasing adherence to physical activity guidelines. The ability of dog-owners to track not only their own activity, but also the health of their dog, may increase dedication and commitment to dog-walking and adherence to physical activity guidelines.

While the findings of this study are applicable to people who are between 25 and 65 years (mean age=35 years), outcomes may differ based on sociodemographic factors, health conditions or expectations. For example, studies have demonstrated that activity trackers are associated with several behavior change techniques that increase physical activity in older adults. [23] Similarly, an activity tracker intervention among patients with osteoarthritis revealed that 87 % took >7,000 steps/day and 77% spent >150 minutes in moderate to vigorous physical activity, but mean daily steps decreased significantly over the 12-week study period.[24]

This study is not without limitations. The clinical trial experienced substantial delays due to COVID-19 pandemic. Subsequently, researchers decided which outcome measures and time points were critical to achieve the research objectives and which protocol procedures could be accurately and safely completed during the pandemic. [25,26] Accordingly, original protocols were revised to mitigate the risks associated with COVID-19, while attempting to maximize evidence acquisition. For example, an additional timepoint of data collection (week-5) for all outcome measures was dropped, whereas dual energy X-ray absorptiometry (DEXA) for body composition was replaced with less accurate BIA. Precautions were also taken to minimize potential difficulties with interpretability of results and statistical analysis due to missing data. Some of the response variables violated the constant variance and the normality assumptions, causing unreliable results of ANCOVA. Furthermore, in this community-based trial, size of each group was limited to 17–19 and the length of wearing of activity trackers was limited to 8 weeks; a larger and longer trial will likely relieve the issues of the assumption violations and detect some of the between-group differences that are currently not significant. Lastly, the measurement of activity is summed up for a week and the wearing time of an activity device is not considered. For future studies, it would be more valid if the wearing time of an activity device is included in the study, such as a ratio of activity measurement divided by the wearing time.

5. Conclusions

In this community-based trial, simultaneous use of activity trackers by dog owners and dogs had no significant effect on activity levels, based on accelerometer data in weeks 1 and 10, although differences in moderate activity was marginally significant and some secondary findings from activity trackers were significant. Future studies should examine if individual led goal-setting and self-monitoring of dog-walking behavior and if non-specific rewards are effective in improving physical activity and adherence to it in short and long-term.

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