Physical activity and lifestyle intervention

Masato Nishiwaki1* and Naoyuki Matsumoto2

1 Faculty of Engineering, Osaka Institute of Technology, 5-16-1 Omiya, Asahi-ku, Osaka 535-8585, Japan
2 Faculty of Environmental Symbiotic Sciences, Prefectural University of Kumamoto, 3-1-100 Tsukide, Higashi-ku, Kumamoto 862-8502, Japan

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Abstract This review summarizes recent findings regarding the status of physical activity and introduces effective methods of intervention. Data from our serial cross-sectional study between 2003 and 2012 suggested that the decline in step counts over the last decade is mainly related to a reduction in non-exercise activity associated with the increased use of cell phones or computers and with playing video games. We then examined the effects of lifestyle interventions using an activity monitor with computerized game functions or an activity monitor and Twitter on physical activity and body composition. These findings suggested that lifestyle interventions using both of these strategies increases daily physical activity and reduces body fat more effectively than using an activity monitor alone. In addition, changes in physical activity and in body fat were significantly correlated. We also applied a randomized intervention to examine an effective method of increasing physical activity levels among college physical education students using a pedometer. We found that using a pedometer and inducing friendly competition or encouragement from peers increased step counts more effectively during soccer classes. These findings therefore have important implications for ensuring compliance with the Physical Activity Reference for Health Promotion 2013 and Active Guide.

Keywords: activity monitor, health, cell phone, personal computer, physical education class, weight loss

Introduction

Higher levels of physical activity (PA) and exercise are associated with lower risk of non-communicable diseases (NCD), such as cardiovascular diseases and cancer1,2). One study has found that insufficient PA and exercise is the 3rd risk factor for mortality due to NCD in Japan, after smoking and hypertension3). Thus, physical inactivity is a major risk factor for NCD2). Increasing PA and exercise is of primary importance to reduce the risk of mortality due to NCD. This review summarizes recent findings regarding the status of PA in Japan and introduces effective interventions to increase levels of PA.

Insufficient physical activity

A previous study reported that step counts is correlated with the amount of PA performed at an intensity of ≥ 3 metabolic equivalents (METs)3), and thus, step counts are widely applied as an objective index of moderate and vigorous PA1,6). The National Health and Nutrition Survey has assessed the annual number of step counts of Japanese people since 1989. The results of the assessment showed that step counts among Japanese fell by 1000 steps/day between 1997 and 20097). A final evaluation by Healthy Japan 21 also found a reduction in steps over the last decade8). If energy intake remains the same, a reduction of 1000 steps/day will induce a 1.0 kg increase in body weight in a single year9). Because physical inactivity is the fourth leading cause of death worldwide10), the decrease in PA is often considered a global pandemic11). Thus, it is essential to increase step counts or PA if the risk for NCD is to be reduced.

The cause of the decline in step counts during the last decade has not been precisely defined. Physical activity can be regarded as consisting of exercise and non-exercise activities12,13). Thus, we examined whether the decline in step counts can be attributed to a reduction in the amount of exercise or non-exercise activities in a serial cross-sectional study of male college freshmen between 2003 and 2012 at the Osaka Institute of Technology9).

Although the characteristics of the participants and PA levels did not significantly differ, trends for average and weekend step counts significantly decreased throughout the decade (Fig. 1A, B, and C). Furthermore, analyses of daily behavior records indicated that weekday and weekend cell phone or computer usage significantly increased and that the amount of weekday time spent playing video games also significantly increased (Fig. 1D and E). Notably, persons with low step counts used a cell phone or

*Correspondence: masato.nishiwaki@oit.ac.jp
computer and played video games more frequently than those with high step counts (Fig. 2A and B). Another recent study found that cell phone usage can disrupt PA and reduce cardiorespiratory fitness determined as peak oxygen consumption14), and that reductions in step counts are associated with increasing Internet addiction levels in a dose-response manner (Fig. 2C)15). Screen time is also inversely associated with isometric trunk muscle strength independently of cardiorespiratory fitness and other confounding factors in youth16). Thus, technological developments such as the Internet and cell phones can reduce daily PA since less energy is needed for non-exercise activities. Although current evidence remains limited, these findings indicate that declining step counts, especially among youth, are mainly related to a reduction in non-exercise activity associated with increased cell phone or computer usage and playing video games. Thus, increases in daily PA habits17), improvements in PA modes18) and better city planning that includes environmental improvements19,20) are needed to increase the amount of non-exercise activities.

Monitoring physical activity and behavioral modification

Pedometers and activity monitors serve as surveillance tools to assess step counts or the amounts of PA. How-
However, a meta-analysis of eight randomized controlled trials and 18 observational studies found a significant increase of 2000 to 2500 steps/day among pedometer users compared with control participants or baseline counts\(^2\)). These findings suggested that the immediate feedback provided by the activity monitor or pedometer is an important motivational feature that serves as a behavioral modification tool. Clemes et al. have also found a significant mean increase of 1000 to 1800 steps/day when participants wear an unsealed pedometer and keep a personal activity log of their daily step counts, compared with wearing a covert (uninformed device and measured values) or a sealed (uninformed measured values) pedometer\(^2\)). That is, being aware of wearing an activity monitor or pedometer and confirming the measured values can induce an increase in daily PA or step counts. Therefore, in addition to being a surveillance tool, pedometers and activity monitors can serve as motivational devices that can induce behavioral modifications. Indeed, many studies have indicated that lifestyle interventions using activity monitors or pedometers can increase regular PA and help to prevent the onset of lifestyle-related diseases\(^2\-26\).

**Effects of an activity monitor with computerized game functions**

We aimed to determine more effective methods of using activity monitors or pedometers as follows. Others have reported that activity monitors and rewards such as being able to watch television induce increases in PA among children\(^27\). Because participants become absorbed in playing interactive video games and perceive them as enjoyable, such games can serve as an additional intervention to encourage compliance with exercise or rehabilitation programs\(^28\-32\). Therefore, wearing an activity monitor as a motivational tool and incorporating behavior-based rewards or a computerized game element might have a collective effect on increasing daily PA. Thus, our pilot crossover study analyzed the effects of a short-term lifestyle intervention using an activity monitor with computerized game functions on PA\(^33\).

Healthy volunteers who participated in the 12-week crossover study were randomly assigned to either group A (six-week game intervention followed by a six-week normal intervention) or group B (six-week normal intervention followed by a six-week game intervention). The participants wore both a Lifecorder EX standard activity monitor (Suzuken Co., Nagoya, Japan) and the Yuuhokei activity monitor with computerized game functions (Bandai Co. Ltd., Tokyo, Japan) during the game intervention and only the standard activity monitor during the normal intervention.

Fig. 3A and B shows that significantly more daily steps were recorded and significantly more PA performed at an intensity of ≥3 METs for the game, than for the normal intervention (both \(P < 0.01\)). The mean differences in
steps and the amount of PA between the game and normal interventions were 1673 ± 1738 steps (21.9 ± 24.0%) and 0.7 ± 0.8 METs (33.6 ± 38.2%), respectively. The Yuuhokei, which was used as the activity monitor with computerized game functions in this study, is visually simple to understand and displays step counts until a goal is achieved. Moreover, the game characters in Yuuhokei usually encourage the users to achieve step-count milestones or physical activity levels. Because the games included in Yuuhokei are based on stories and tales that are very famous in Japan, such as Space Battleship Yamato, the Rose of Versailles, and Section Chief Kousaku Shima, participants easily became absorbed in increasing PA to clear the game. Collectively, the game story, scenes, and characters might help to motivate individuals to walk or be active and make them even more aware of daily PA levels and step goals. Therefore, these findings suggest that short-term interventions using an activity monitor with computerized game functions increases PA more effectively than those using a standard activity monitor.

However, despite a significant correlation between step counts obtained from the Yuuhokei and the Lifecorder EX (r = 0.92), significantly fewer steps were counted by the former than the latter (7165 ± 4284 steps/day vs. 10132 ± 4841 steps/day, P < 0.01)\textsuperscript{34}). The accuracy of the step counts detected by Lifecorder EX is calibrated during the manufacturing process according to the Japanese Industrial Standards (JIS), and the widely accepted error during walking on a treadmill is within 1\%\textsuperscript{35-37}). Therefore, these results infer that although relative changes in daily individual step counts determined from the Yuuhokei might help to evaluate daily PA, the application of absolute step counts obtained from this device as a proxy assessment of daily PA levels might be limited. If the goal is 10000 steps/day, then the target value for each game to proceed to the next scene should be set at 8000 steps, which approximately corresponds to 10000 steps counted by the Lifecorder EX.

**Effects of an activity monitor and Twitter**

One study has found that exercising with a virtual partner through a brief video chat via services such as Skype can improve aerobic exercise performance across multiple sessions\textsuperscript{38}). These findings suggested that friendly competition or encouragement from online partners can increase motivation in both exercise and non-exercise activities, thereby increasing daily PA. Although recent reports have described a web-based PA diary\textsuperscript{39-41}), not everyone can utilize large-scale systems. Thus, we considered social networks such as Twitter, which enables users to send and read short 140-character messages (tweets) that an indefinite number of individuals can easily and immediately share or exchange via tweets, retweets, and timelines. In addition to being aware of wearing the monitor and confirming measured values, adding Twitter might promote daily PA or reduce sedentary behavior through friendly competition with, and/or encouragement from online partners. Thus, we investigated the effects of a randomized lifestyle intervention using an activity monitor and Twitter on PA\textsuperscript{42}).

Healthy participants were randomly assigned to either a Normal intervention group that wore a Lifecorder EX activity monitor or a Twitter intervention group that wore the same activity monitor and tweeted about their daily steps or PA for six weeks. An observer read the tweets
from each participant and commented about PA. The protect mode was configured for each account to safeguard the data of each participant.

Daily PA (step counts and amount of PA) did not significantly differ at week one between the groups and did not significantly differ over the six-week experimental period in the Normal group. In contrast, step counts (Fig. 4A) and the amount of PA (Fig. 4B) gradually increased from weeks one to six in the Twitter group from 8542 ± 3158 to 12700 ± 3935 steps/day and from 2.5 ± 1.2 to 4.6 ± 2.3 METs·h/day (both P < 0.01). Moreover, step counts significantly declined immediately after the end of the experimental period in the Twitter group (Fig. 4C). Friendly competition or encouragement from online partners such as other participants in the Twitter group in addition to being aware of wearing an activity monitor and confirming the measured values might help to motivate participants to become more active and cause them to become even more conscious of daily PA levels and step goals. Therefore, these data indicated that daily PA increased more effectively when a lifestyle intervention comprised an activity monitor and Twitter rather than an activity monitor alone.

![Graph A](image1.png)  ![Graph B](image2.png)  ![Graph C](image3.png)

**Fig. 4** Comparisons of time-course changes in physical activity during Twitter intervention. Comparisons of time-course changes in step counts (A) and physical activity at an intensity of ≥ 3 METs (B). *P < 0.05 and **P < 0.01 vs. week 1; †P < 0.05 and ††P < 0.01 vs. the Normal group. Data are shown as means ± SD in A and B. Comparisons of time-course changes in steps in the Normal intervention group (n = 5), Twitter intervention group (n = 5), and Twitter-stop group (n = 5) (C). Twitter-stop group, Twitter usage was stopped after the week 6 and the participants only wore the activity monitor. **P < 0.01 vs. week 1; ††P < 0.01 vs. week 6. Data are shown as means ± SEM in C. Daily physical activity in the Twitter group gradually increased from week 1 to week 6, but not in the Normal group. In addition, step counts significantly declined immediately after the end of Twitter usage (Nishiwaki et al., 2013 and unpublished observation).
Increases in physical activity and physiological parameters

Although epidemiological studies indicated the importance of PA for health\(^1,10\), whether lifestyle intervention can actually induce an improvement in physiological parameters such as body composition or blood pressure (BP) remains unclear. A recent study found that in general, an increase in PA is proportionally associated with a reduction in body fat within 16 weeks\(^43\). Therefore, if a lifestyle intervention using an activity monitor with computerized game functions or an activity monitor and Twitter could increase the daily PA, then body weight and fat should become reduced and changes in body composition and PA should correlate. Thus, we examined the effects of increasing PA via a lifestyle intervention on body composition or BP\(^44\).

Six weeks of intervention using an activity monitor with computerized game functions significantly reduced body weight, body mass index, and body fat determined using the impedance method (\(P < 0.01\)). Significantly more fat was also lost in a Game than in a Normal intervention (\(P < 0.05\))\(^44\) and body fat and waist circumference were significantly reduced after an intervention using an activity monitor and Twitter. In fact, significantly more body fat was lost after the Twitter, than the Normal intervention (-1.1 ± 0.2 kg vs. -0.1 ± 0.3 kg; \(P < 0.05\)) (Fig. 5A), and changes in PA and body fat significantly correlated (\(r = -0.713, P < 0.05\)) (Nishiwaki et al. under review). Although baseline PA and dietary intake were unclear in this population, the participants in the Twitter group expended 11020.6 ± 1364.2 kcal (amount of PA at intensity of ≥ 3 METs (METs·h) × body weight (kg) × 1.05 × period of six weeks). A 1.0 kg reduction in body fat generally requires the expenditure of 7000 to 8000 kcal\(^32\). Because the Twitter group lost 1.1 ± 0.2 kg of body fat, the degree of fat reduction was approximately consistent with the amount of PA in which the Twitter group performed. Thus, our results indicated that more body fat can be lost during lifestyle interventions associated with increases in PA levels.

Our data indicated that diastolic BP, mean BP, pulse pressure, and pulse rate did not significantly change after six weeks of interventions. However, systolic BP was slightly, but significantly, reduced after the interventions (\(P < 0.05\))\(^44\); it was reduced in not only interventions using Game and Twitter, but also in those using a normal activity monitor. Our results support previous findings that walking induces a reduction in BP\(^45\). Therefore, these findings suggest that short-term lifestyle intervention using an activity monitor induced a reduction in systolic BP.

Application of a pedometer to physical education class or sports activity

Understanding that exercise is also important in increasing the amount of PA, we performed a randomized intervention study to determine a method of effectively increasing PA levels during college physical education (PE) classes using a pedometer\(^46\).

We randomly assigned 159 male college freshmen students to a Control or an Intervention group based on...
filiation courses. Both groups participated in four 90-min PE classes and initially wore a sealed (uninformed measured values) pedometer to assess baseline step counts at the first class. The Control group continued to wear a sealed pedometer for the next three classes, whereas the Intervention group wore an unsealed pedometer (informed measured values) and recorded their step counts in a team activity log. Victory and defeat were decided by both the step counts of team members and the soccer game scores. Thus, the students in the Intervention group were encouraged to increase their step counts.

Because we excluded all data missing values from statistical analyses, data for the remaining 43 (the Control group) or 62 (the Intervention group) participants were analyzed. Baseline step counts per class did not significantly differ between the groups, and the step counts did not significantly change over time in the Control group. However, step counts for the Intervention group gradually increased between baseline and the fourth class (4502 ± 123 steps/class vs. 5539 ± 119 steps/class; P < 0.01; Fig. 6A). Furthermore, we analyzed the effects of a half-intervention on step counts. The participants in this half-intervention (n = 51) wore an unsealed pedometer and recorded their step counts in an individual activity log, and did not compete against other teams for step counts. Fig. 6B shows a significantly greater change in step counts from baseline to fourth class for the Intervention group compared with the Control group and no significant difference between the Control and the Half-intervention groups. Thus, in addition to being aware of wearing a pedometer and confirming measured values, friendly competition or encouragement from other students taking the same class might cause participants to become more active. Such PE classes using a pedometer might also positively affect game and point scores in college PE classes47). Collectively, our findings suggest that wearing pedometers can increase step counts more effectively during PE classes when the players participate in friendly competition or are encouraged by other students.

Summary

A lack of physical activity is often considered as a global pandemic and the reductions in step counts or PA cannot be ignored to reduce the risk for NCD. Some evidence indicates that the decline in step counts over the last decade is mainly related to a reduction in non-exercise activity associated with increased cell phone or computer usage and playing video games. Therefore, pedometers or activity monitors that can induce behavioral modifications should be used as motivational devices to increase step counts or PA. Our findings suggest that lifestyle interven-
tions using an activity monitor with computerized game functions or an activity monitor and Twitter increase daily PA and reduce body fat more effectively than an activity monitor alone. In addition, using pedometers along with friendly competition or encouragement from peers during PE activities might increase step counts among college students more effectively than participating in such activities without these stimuli. These findings therefore have important implications for ensuring compliance with the Physical Activity Reference for Health Promotion 2013 and Active Guide44,45.

Conflicts of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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