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Original Article

# A Cluster Randomized Controlled Trial on the Effects of Technology-aided Testing and Feedback on Physical Activity and Biological Age Among Employees in a Medium-sized Enterprise

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ABSTRACT

*Background:* It has been suggested that engaging technology can empower individuals to be more proactive about their health and reduce their health risks. The aim of the present intervention was to study the effects of technology-aided testing and feedback on physical activity and biological age of employees in a middle-sized enterprise.

*Methods:* In all, 121 employees (mean age 42 ± 10 years) participated in the 12-month three-arm cluster randomized trial. The fitness measurement process (Body Age) determined the participants' biological age in years. Physical activity was measured with the International Physical Activity Questionnaire Short Form.

*Results:* Physical activity did not change during the intervention. Biological age (better fitness) improved in all groups statistically significantly ($p < 0.001$), but with no interaction effects. The mean changes (years) in the groups were −2.20 for the controls, −2.83 for the group receiving their biological age and feedback, and −2.31 for the group receiving their biological age, feedback, and a training computer.

*Conclusion:* Technology-aided testing with feedback does not seem to change the amount of physical activity but may enhance physical fitness measured by biological age.



## 1. Introduction

Employer-sponsored wellness programs have achieved significant improvements in cardiovascular risk factors [1], such as weight management and waist circumference [2,3]. Participation in well-structured worksite wellness programs may increase health and life satisfaction for employees, and they appear to help employees develop and maintain healthy behaviors [4–7]. Participation in workplace physical activity programs can also be associated with improvements in the mental component of health-related quality of life, although the physical activity level remains the same [8]. However, fewer small businesses adopt workplace health promotion programs compared with large businesses [9].

While participation in worksite wellness programs may increase employees' health and life satisfaction, technology-aided methods are expected to increase encouragement and motivate changes in health behavior better than, for example, the traditional testing of physical capacity [10]. Workplace health promotion interventions may improve physical activity and dietary behavior, and encourage a healthy weight, but there is no evidence of increased efficacy associated with specific intervention types [11]. Previous studies are inconclusive, and some have suggested that the effectiveness of interventions in physical activity and productivity-related outcomes in occupational settings could be poor [12,13]. Thus, it has also been suggested that engaging technology can empower individuals to be more proactive about their health and reduce their health risks [14].

Our study concentrated on studying the effects of technology-aided methods and measurements of physical activity using the Body Age method. Body Age is a fitness assessment method and a product concept developed in the late 1980s. Body Age applies a person's demographics, health status, lifestyle questionnaires, and

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fitness assessments. Reliable and repeatable assessments are made possible by hardware provided by the Body Age System, herein referred to as the test system (Polar Electro Inc., Kempele, Finland). The fitness assessment results are characterized by a Body Age score, which defines the person's biological age (in years). The software of the test system generates an assessment report automatically [15].

Heterogeneity of the age-related physiological changes is shown by the "biological age," which determines the rate of aging experienced by each individual. Biological age is defined as the functional capability of a human, and the selected biomarkers encompass various complex physiopathological factors related to intrinsic and extrinsic physiological and functional aging. It can be measured, for example, by functional capacity tests, blood tests, and skin, retinal, and strength tests [16]. The biological age index is commonly constructed from a number of the most reliable biomarkers of aging [17]. Compared with individual biomarkers, the index has been shown to be a reliable biomarker of mortality, and a cognitive and physical performance prognostic factor. The correlation is not demonstrated only with individual biomarkers [17]. To our knowledge, the applicability of Body Age to occupational health services has not been studied previously.

The purpose of the present study was to determine the effects of technology-aided testing and feedback given (Body Age score) on physical activity and biological age during a 12-month follow-up period in a cluster randomized controlled study in a medium-sized enterprise.

## 2. Materials and methods

### 2.1. Study sampling and design

This study was carried out among employees of a medium-sized enterprise in recycling. The circular economy company provides comprehensive environmental management services. The intervention project took place in its main site (Riihimäki, Finland) in the years 2008–2009. The company employed both blue and white collar workers, the majority working in manufacturing but a part also in administration. All employees ($n = 220$) were invited to participate in the physical activity intervention program. Both the occupational health nurse and the executive director informed all the employees beforehand, and everyone could sign up for the study. In addition, electronic information channels delivered general information about the study. In all 67% (149) of the employees registered for the study and were cluster randomized into three groups based on age, sex, and occupation (blue and white collar). The study was carried out through the occupational health service in the company and coordinated by an occupational health nurse. An ethics committee approval statement was obtained from the Lahti Region Hospital Ethics Committee. Written informed consent was obtained from the participants.

### 2.2. Participants

The inclusion criteria were readiness to participate in the study, age between 18 and 64 years, and the occupational physician in the company approving the self-reported medical history. The exclusion criteria were pregnancy, coronary artery disease, uncontrolled hypertension (blood pressure > 200/110 mmHg), and the use of a pacemaker. Contraindications for the study also included severe arrhythmias, myocardial infarction or bypass surgery in the last 6 months, angioplasty or thrombolytic therapy, valvular heart disease, or other problematic heart failures. Severe symptoms of stress, an unbalanced systemic disease, acute infection, and recent severe injury or surgery were also contraindications for the study.

Study participants' characteristics are shown in Table 1. During the 1st 3 months, 11 employees were made redundant for economic and production reasons, and they therefore dropped out of the study. The analysis includes employees with results from baseline as well as the 6-month and 12-month follow-ups ($n = 121$). There were almost no significant differences at baseline in background and outcome variables. All groups were similar except for the wall sit. Body Age was higher than chronological age in all groups at baseline.

### 2.3. Test system and procedure

The Body Age System is primarily targeted for use in fitness and health-related fitness environments to motivate individuals to be physically active for better health and fitness, and to improve their overall well-being.

The Body Age measurement process is used to form a biological age [15]. The measurement includes muscular strength, flexibility, aerobic fitness, and body composition by means of tests performed

**Table 1**
Demographic and clinical characteristics of the study participants by group

| Variables | Group | | | $p$ |
|---|---|---|---|---|
| | A ($n = 42$) | B ($n = 43$) | C ($n = 36$) | |
| Demographic variables | | | | |
| No. of men, $n$ (%) | 34 (81) | 35 (81) | 27 (75) | 0.67 |
| Age (y), mean (SD) | 42 (10) | 43 (10) | 40 (10) | 0.33 |
| Body mass index (kg/m$^2$), mean (SD) | 27.2 (4.6) | 26.8 (3.9) | 26.3 (3.9) | 0.63 |
| Current smoker, $n$ (%) | 9 (21) | 10 (23) | 11 (31) | 0.70 |
| Clinical variables | | | | |
| Blood pressure (mmHg) | | | | |
| Systolic, mean (SD) | 135 (11) | 136 (9) | 138 (12) | 0.60 |
| Diastolic, mean (SD) | 93 (14) | 93 (12) | 91 (12) | 0.59 |
| Body age difference from chronological age (years), mean (SD) | 4.23 (5.21) | 2.59 (5.86) | 2.52 (6.85) | 0.24 |
| Body age index (years), mean (SD) | 46.1 (11.0) | 45.9 (12.4) | 42.6 (12.0) | 0.31 |
| Body fat, % (SD) | 26.6 (9.1) | 25.3 (7.0) | 26.5 (9.1) | 0.68 |
| Biceps strength (kg), mean (SD) | 41.7 (11.7) | 44.3 (12.2) | 41.0 (13.2) | 0.39 |
| Wall sit (s), mean (SD) | 111 (52) | 123 (61) | 145 (64) | 0.02* |
| Sit and reach (cm), mean (SD) | 33.8 (8.5) | 34.5 (8.1) | 37.1 (9.2) | 0.17 |
| Crunch repetitions, mean (SD) | 31.8 (15.4) | 38.2 (15.9) | 33.5 (17.8) | 0.13 |
| $VO2_{max}$ (mL/kg/min), mean (SD) | 35.3 (7.1) | 36.4 (8.8) | 39.0 (10.1) | 0.13 |

*Statistically significant according to the $p < 0.05$ level.

in a standardized manner. Selected tests are based on easy access and individual tests are based on research evidence. The measurement category comprises assessments that typically characterize the person's physiological state with measurable variables. The measurement category includes four subcategories, which are related to the individual's biometrics, cardiovascular characteristics, body composition characteristics, and musculoskeletal characteristics.

The Body Age score ($S^{BA}$) is expressed with the following formula [15]:

$$S^{BA} = CA + \sum_{i=1}^{N} \Delta_i^{MC} \times W_i^{MC} + \sum_{j=1}^{M} \Delta_j^{AC} \times W_j^{AC}$$

where $CA$ is the test participant's chronological age (years), and $\Delta_i^{MC}$ and $W_i^{MC}$ are the age value and corresponding weight (kg), respectively, arising from assessment $i$ in the measurement category. Parameters $\Delta_j^{AC}$ and $W_j^{AC}$ represent the age value and corresponding weight, respectively, arising from assessment $j$ in the appraisal category. Indices $j$ and $i$ run over the number of assessments applied in the measurement and appraisal categories, respectively. The age value of each assessment represents an age increment or decrement of the Body Age, and depends on how the corresponding test results ranks in statistical data of similar demographics. The ranking is based on generally accepted data provided by scientific publications. For Body Age calculation, the sex- and age-specific classification of each assessment is used. The number of classifications varies from five to seven depending on the assessment. Depending on the number of classifications, each class of each assessment affects Body Age. For example, for the cardiovascular assessment, a seven-scale classification for $VO2_{max}$ is used as a reference [18]. If the test participant scores in the "very low" category, this results in 4 years being added to his/her Body Age score. If the test participant scores in the "elite" category, this results in 4 years being subtracted from his/her Body Age.

The Body Age measurement process was carried out as follows: personal information (name, date of birth) and the completed, prefilled forms were inputted into the coded computer system. Each participant's weight (kg) and height (m) were measured, and results were inputted into the system. The measurement protocol continued with a nonexercise fitness test based on heart rate variability (Polar Electro Inc., Kempele, Finland) [15]. Blood pressure was measured in a sitting position after a 5-minute rest period. The physical tests began with a 90° wall sit test. The participant sat against a wall with knees bent at a 90° angle to support his/her body weight for as long as possible. Static upper-body power generation properties were tested with a 5-second biceps curl, with the forearm bent at an angle of 90° while the participant was in a standing position. The performance was repeated three times. Abdominal muscle endurance was measured using 60-second maximum crunch repetition performance with a knee angle of 90°. The flexibility assessment consisted of a modified sit-and-reach test implemented with a handle integrated into the test system. After the assessments and calculation of the Body Age score, the test system automatically generated a test report comprising feedback from the overall assessment [15].

### 2.4. International Physical Activity Questionnaire

The International Physical Activity Questionnaire Short Form (IPAQ-SF) has been recommended as a cost-effective method for assessing physical activity [19]. It is widely used in worksite wellness programs to obtain physical activity estimates. In the present study, the purpose of the IPAQ-SF was to obtain comparable estimates of physical activity, and it was used to observe activity estimates in general. Continuous score levels were used and the results expressed as metabolic equivalent of task (MET)-min/week: MET level × minutes of activity × events per week. METs are the multiples of resting metabolic rate and MET-min scores are equivalent to kilocalories for a 60-kg person.

### 2.5. Intervention

Body Age measurement and physical activity questionnaires were conducted at 0 months, 6 months, and 12 months. The participants completed all outcome forms (and the informed consent form at baseline) before each Body Age measurement. At baseline, group A received only the separate test results (not the Body Age index). Group B received the Body Age results (index in years). Group C received both Body Age and separate test results, as well as a training computer (FT60; Polar Electro Inc.) to support voluntary training. The report included all the results related to the overall population results. The participants were given a separate training program, and an occupational health nurse went through the report in detail with each participant.

Between the 6$^{th}$ and 12$^{th}$ month of the intervention, all participants were contacted by phone monthly. The research nurse called them to complete the physical activity questionnaire and provided guidance if needed.

### 2.6. Statistical methods

The data are presented as means with standard deviations or as counts with percentages. Statistical comparisons were made using the chi-square test, Fisher's exact test, analysis of variance, or bootstrap-type analysis of variance. In the case of violation of assumptions (non-normality), a bootstrap-type test was used. Normality of the variables was tested using the Shapiro–Wilk $W$ test. Repeated measures were analyzed using generalizing estimating equation models with an unstructured correlation structure. Generalized estimating equations were developed as an extension of the general linear model (e.g., regression analysis) to analyze longitudinal and other correlated data. Generalizing estimating equation models take into account the correlation between repeated measurements in the same individual; models do not require complete data and can be fit even when individuals do not have observations at all time points. A difference between the variables was considered statistically significant for $p < 0.05$.

## 3. Results

The Body Age difference decreased significantly during the intervention, as shown in Fig. 1. However, no interaction effect was found. The mean changes (years) in the groups were as follows: A −2.20 [95% confidence interval (CI): −3.09 to −1.30], B −2.83 (95% CI: −3.76 to −1.91), and C −2.31 (95% CI: −3.24 to −1.37); there were no statistically significant differences in the changes between the groups ($p = 0.13$). Changes over time were statistically significant in all groups ($p < 0.001$).

There were significant differences in physical activity between the groups ($p = 0.027$), however the changes were not significant ($p = 0.98$) and with no interaction effects ($p = 0.63$) as shown in Fig. 2.

The mean changes (MET/min/wk) in the groups, from baseline to the end, were as follows: A −89 (95% CI: −1,109 to 926), B −17 (95% CI: −1,021 to 987), and C 127 (95% CI: −904 to 1,158).

## 4. Discussion

The Body Age score decreased in all groups, which suggests that the participants' fitness increased, but there were no statistically significant differences between the groups in either body age or physical activity after the intervention. Thus, awareness of Body Age did not have any effect on biological age. Our results contradict other studies that show that employer-sponsored wellness programs have achieved significant improvements in cardiovascular risk factors, such as weight management and waist circumference [1–3]. Participation in well-structured worksite wellness programs have also increased health and life satisfaction for employees, and helped employees develop and maintain healthy behaviors [4–7]. Participation in workplace physical activity programs has also been associated with improvements in the mental component of health-related quality of life, even though the physical activity level remains the same [8].

Self-reported physical activity levels (according to the IPAQ-SF) did not change during the intervention period. One possible explanation could be that the measurement of physical activity was unsatisfactory. This is typically an inherent bias in self-reported data, as they overestimate physical activity as measured by objective criterion [20]. Therefore, if the IPAQ-SF overestimates physical activity, the finding that there was no change in self-reported physical activity during the intervention period could actually mean a real decrease in physical activity.

A limitation of the study was that the Biological Age method has not been tested for reliability, although the method includes separate measurements that all have widely been used and tested [15].

During the study, however, all groups improved their biological age during the 12 months. The biggest improvements in time occurred within the first 6 months. Systolic blood pressure levels improved significantly and thus partly explain the results. Blood pressure is a sensitive measure, which may also be affected, in addition to physical activity, by mental stress. Mental stress was minimized by that the blood pressure was measured after a rest period of 5 minutes. Thus, the testing could be, at least in baseline, a more stressful situation than during the follow-ups. The feedback could also have affected the participants' health behavior in many ways, such as affecting their diet, sleep quantity, and everyday choices. The improvement in biological age could also partly be explained by a learning effect: the participants learned how to do the different tests. The change in biological age was rather fast, and a longer follow-up should be important in future interventions to see if the changes persist in the long run.

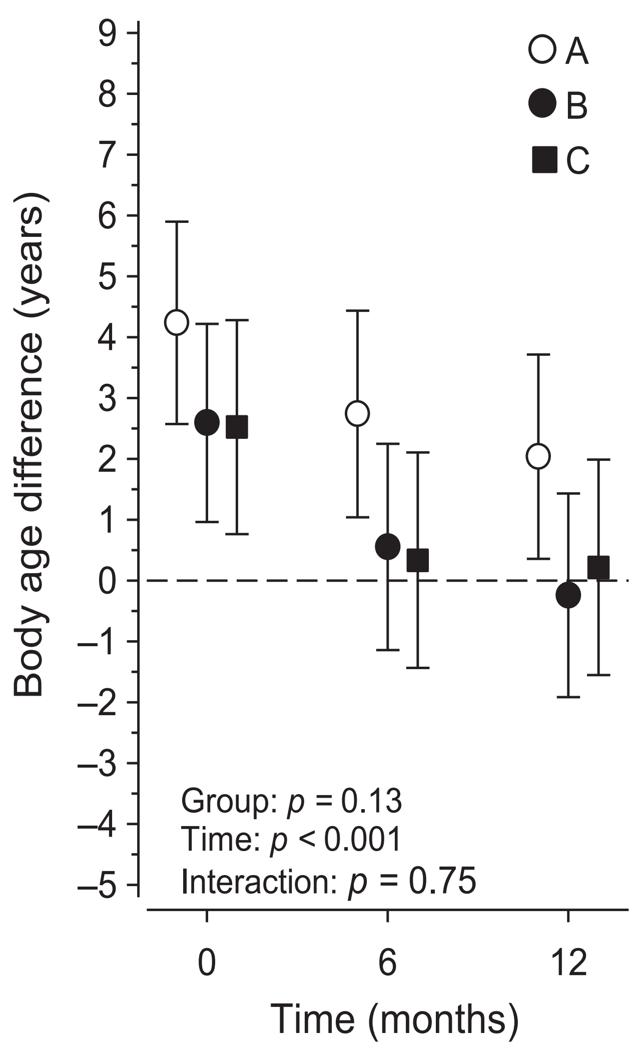


**Fig. 1.** Body age differences (years, mean, and 95% confidence interval) between groups during the intervention ($n$ = 121). Groups are expressed with letters A (controls, traditional feedback), B (biological age and feedback), and C (biological age, feedback, and training computer).

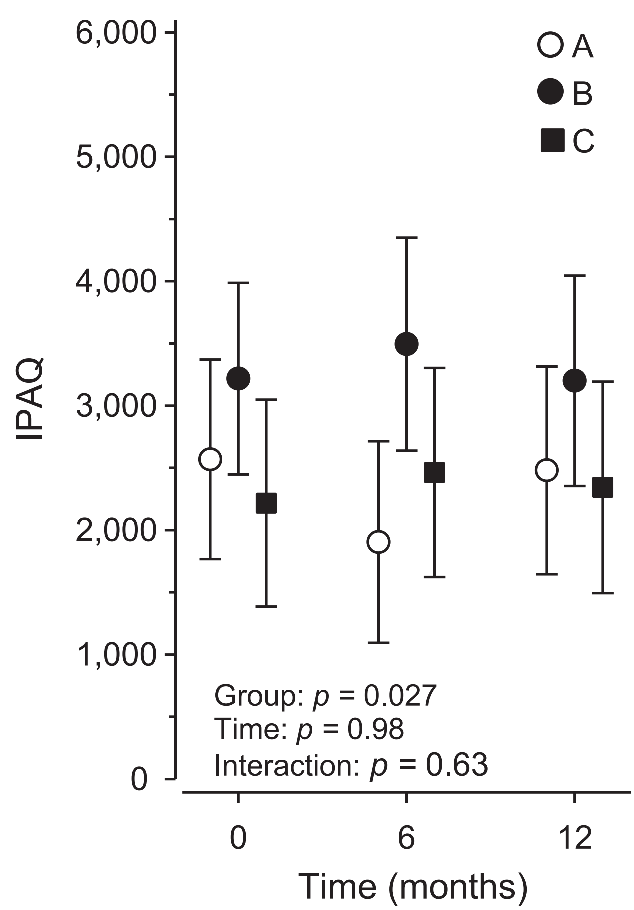


**Fig. 2.** Physical activity (IPAQ-SF; MET/min/wk during the intervention, mean, and 95% confidence interval) in the groups ($n$ = 121). Groups are expressed with letters A (controls, traditional feedback), B (biological age and feedback), and C (biological age, feedback, and training computer). IPAQ-SF, International Physical Activity Questionnaire Short Form; MET, metabolic equivalent of task.

The study was a cluster randomized controlled study. The program involved 70% of the company's employees. Participation was voluntary, and we cannot rule out that those who volunteered may more likely have other lifestyle activities that are positive for reduction of biological age than those who did not participate, which may have affected the results.

The self-training does not seem to have been sufficient, although the participants received appropriate guidance in increasing physical activity. Organized training sessions or personal trainers could have been a better solution, although self-training with possible backup, if needed, is a very realistic and economical situation for most companies.

A strength of the study was the good compliance by the management, occupational health care, and employees (the participation rate was 70% at baseline). The program motivated and engaged the people involved, although this was not adequate to help them reach a higher level of fitness. The Body Age method was also perceived as quick and easy to use, and gave the occupational health care information about the health and fitness of the employees. The intervention was successfully completed by the employees. They were enthusiastic regarding participation, and all measurements were conducted in accordance with a set pretested protocols. The basis of this intervention was easy to manage, and the participants calculated measurements during their workday. Days were organized with a similar protocol to involve all participants. A limitation is that the study was not blinded, because the employees knew and talked to each other during working hours, and, in addition, most of them lived in the same small town. Therefore, the workers could discuss the physical activity and test results with each other. Thus, there could have been a Hawthorne effect in the reference group (A), which received only individual test results but not the body age. This disturbs and certainly affects the randomized and controlled study design. If the study would have been carried out in different cities, the results might have differed.

The present study suggests that technology-aided testing and feedback do not seem to change the level of an individual's physical activity but may enhance physical fitness measured by biological age.

## Conflicts of interest

All authors have no conflicts of interest to declare.

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