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Original Article

Internet of things-based lifestyle intervention for prostate cancer patients on androgen deprivation therapy: a prospective, multicenter, randomized trial

Yong Hyun Park[1], Jong In Lee[2], Ji Youl Lee[1], In Yae Cheong[3], Ji Hye Hwang[3], Seong Il Seo[4], Kang Hyun Lee[5], Ji Sung Yoo[6], Seung Hyun Chung[6], Yekyeong So[7]

[1]Department of Urology, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Republic of Korea; [2]Department of Rehabilitation Medicine, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Republic of Korea; [3]Department of Physical and Rehabilitation Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea; [4]Department Urology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea; [5]Department of Urology, Center for Prostate Cancer, Research Institute and Hospital, National Cancer Center, Goyang, Republic of Korea; [6]Department of Rehabilitation Medicine, Research Institute and Hospital, National Cancer Center, Goyang, Republic of Korea; [7]Division of Healthcare Technology Assessment Research, National Evidence-based Healthcare Collaborating Agency, Seoul, Republic of Korea

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Abstract: Androgen deprivation therapy (ADT) has several adverse effects including loss of libido, osteoporosis, and metabolic complications. We aim to examine whether the Smart After-Care (SAC) service, an Internet of Things (IoT)-based lifestyle intervention, affects clinical outcomes in prostate cancer (PCa) patients on ADT. A prospective, multicenter, randomized trial including 172 patients randomly assigned to the SAC or control group was conducted. The SAC group was provided with a smartphone application providing a personalized exercise program, daily activity monitoring, and diet counselling. The control group was briefly educated on the exercise program using a paper brochure. The primary endpoint was increase in cardiorespiratory endurance assessed using the 2-minute walking test (2MWT). Secondary endpoints included improved muscle strength (hand grip strength test and 30-second chair stand test), short physical performance battery, body composition, and health-related quality of life (EORTC-QLQ-C30 and PR25). Participants in both groups showed significant improvement in the 2MWT and 30-second chair stand test after 12 weeks of intervention. Greater improvement in the 2MWT was observed in the SAC group than in the control group. Significantly increased body fat ratio was observed in both groups; however, decreased skeletal muscle mass was observed only in the control group. Marginal improvement in skeletal muscle mass was observed over time in the SAC group when compared with that in the control group. Both groups showed improvement in all physical scales in the EORTC-QLQ-C30 questionnaire, and the SAC group showed a significant interaction of group and time for social functioning scales. SAC improved cardiorespiratory endurance, sarcopenic obesity, and health-related quality of life in patients with PCa on ADT.

Keywords: Prostate cancer, androgen deprivation therapy, lifestyle intervention, internet of things, smart after-care, randomized trial

Introduction

Cancer is a major public health problem worldwide, associated with tremendous health and economic burdens. Although the relative survival rate of cancer has increased, it is still a leading cause of death based on data from the American Cancer Society [1]. Lifestyle behaviors including physical activity and diet, and lifestyle-related factors, including blood pressure and body composition, are important causes of morbidity and mortality in patients with cancer [2, 3]. Moreover, these patients often experience multiple physical, functional, and psychosocial problems during and after treatment [4]. Preventive care for these lifestyle

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1) Histologically confirmed prostate cancer 2) Patients on androgen deprivation therapy 3) Proper smartphone	1) History of treatment for other malignancy within the past 3 months 2) Serious cardiovascular or pulmonary disease that limits exercise 3) Bone metastasis causing severe pain during exercise or high risk for pathologic fracture 4) ECOG performance status ≥ 3 5) Unable to perform 2-minute walk test

ECOG, Eastern Cooperative Oncology Group.

factors is important for all cancer survivors and helps improve their physical condition and emotional balance. However, more than half of cancer survivors report having insufficient information and support on how to deal with these problems [5].

Prostate cancer (PCa) is the most common cancer among men in Western countries [1]. Androgen deprivation therapy (ADT) is an effective treatment used in almost half of the patients with PCa at some point during their treatment [6, 7]. It has numerous adverse effects including vasomotor symptoms, bone mineral density loss, increased body weight and fat, decreased lean body mass, increased cardiovascular disease risk, and impaired quality of life (QoL) [8]. Many researchers have demonstrated the potential of exercise, diet, and nutritional interventions in mitigating ADT-induced adverse effects [9].

Recent advances of 'Internet of Things' (IoT) technology have the potential to improve patient satisfaction and the efficacy, quality, and timeliness of healthcare service delivery [10-12]. IoT-based interventions, including monitoring through wearable devices, pragmatic counselling, assisted planning, education, and emotional support, can reach many patients at once and are accessible anytime and anywhere [13]. While this technology might be useful in PCa, to the best of our knowledge, no study has investigated its effectiveness for this specific cancer.

The Smart After-Care (SAC) service is an IoT-based platform that integrates mobile sensor networks; individualized exercise and diet programs; life-log analysis to detect and transmit any abnormal parameters to the platform; and a mobile communication network for patients, physicians, and counsellors. We aim to examine the effects of SAC on clinical outcomes in patients with PCa on ADT through intervention for several risk factors, disease monitoring, and rehabilitation.

Materials and methods

Systematic review of previous studies

PubMed, the Cochrane Library, the CINAHL database, and EMBASE were systematically searched for literature published between January 1990 and December 2018. The inclusion criteria were specified by Population, Intervention, Control, Outcomes, Study design framework to include (1) Population: men with histologically confirmed PCa undergoing ADT; (2) Intervention: any IoT-based lifestyle intervention including exercise, diet, education, monitoring, coaching, and counselling; (3) Control: control group not receiving any intervention at any time point during the trial or receiving conventional lifestyle intervention; (4) Outcomes: physical function, muscle strength, body composition, and/or health-related QoL; and (5) Study design: randomized controlled trials or controlled trials. Only full-text English or Korean articles published in peer-reviewed journals were included in the search.

Patients and study design

This prospective randomized controlled multicenter trial was approved by the Institutional Review Board of each hospital and carried out in accordance with the respective guidelines; it was registered on the ClinicalTrial.gov database (identifier NCT03264209). Two hundred and six patients with PCa on ADT were recruited from three hospitals in Korea. After providing written informed consent and undergoing baseline assessments, patients who met the inclusion and exclusion criteria (**Table 1**) were randomly assigned to the SAC or control group in a 1:1 ratio based on a computer-gener-

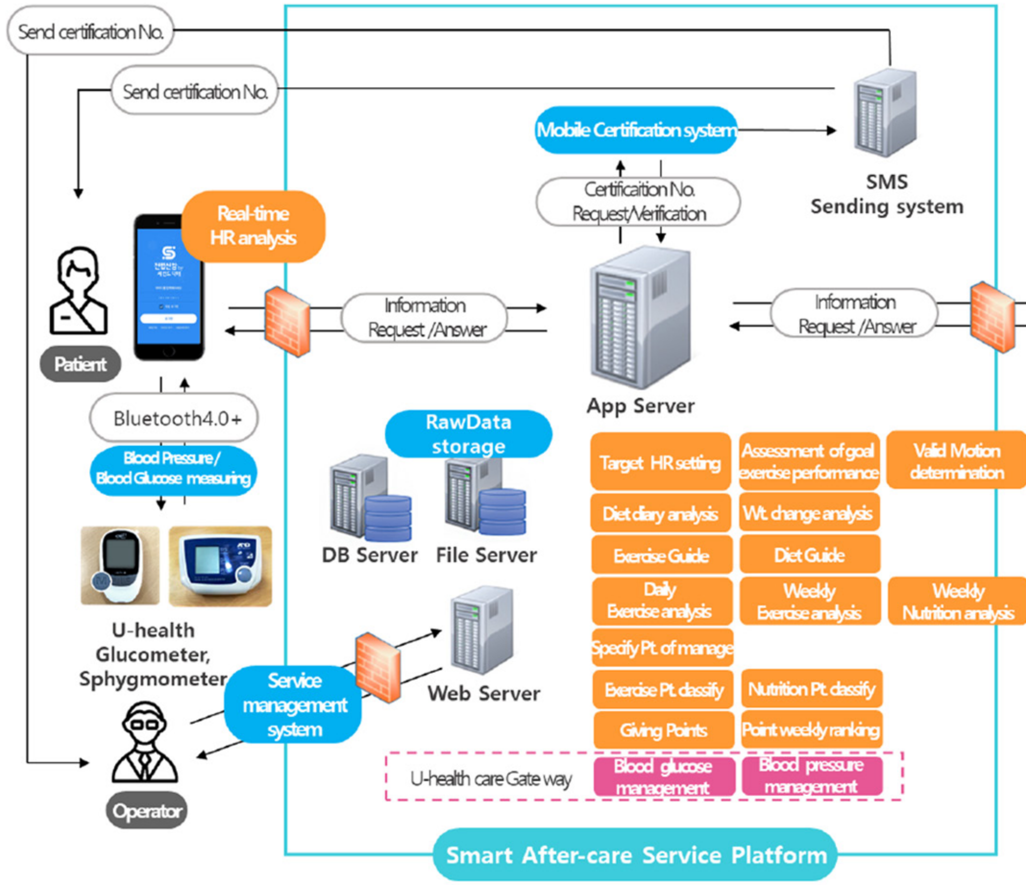

Figure 1. Schematics of the Smart After-Care platform.

ated randomization sequence. The randomization process was guaranteed and managed exclusively by the Catholic Medical Center Clinical Research Coordination Center which had no role in recruitment. Permuted-block random allocation with varying block sizes was performed. The primary endpoint was improved cardiorespiratory endurance measured by the 2-minute walking test (2MWT) performed on a 15.2 m hallway out-and-back course. Patients were instructed to walk as fast as they could until asked to stop at 2 minutes; the distance covered was recorded. The secondary endpoints were improvements in muscle strength (hand grip strength test and 30-second chair stand test), short physical performance battery (SPPB), physical measurements including body composition, and health-related QoL using the EORTC-QLQ-C30 and PR25 questionnaires. A handgrip strength test was used to assess upper extremity muscle strength using a handheld dynamometer. Patients were instructed to apply maximal power for 3 seconds with the shoulder adducted and neutrally rotated; elbow flexed at 90°; and forearm and wrist in a neutral position. Three attempts were allowed with each hand, and the best score (kg) for each was recorded [14]. A 30-second chair stand test was used as a measure of lower extremity muscle strength. Each patient was seated in the middle of the chair (seat height was 40 cm, with a backrest but no armrests) with their backs straight and both arms folded across their chest. The patients were instructed to stand up and sit down repetitively and encouraged to complete as many full stands as possible for 30 seconds while the instructor kept count [15].

Development of the Smart After-Care system

The SAC system comprises a commercially available Android-based smartphone, a smartphone application, a web-based platform, and a smartband (Neofit band, KT, Korea) (**Figure 1**). All software components were designed and

Figure 2. Representative screenshots of the Smart After-Care mobile phone applications.

built by the research team (**Figure 2**). The SAC application for patients consists of six components: (1) individually prescribed exercise program, (2) daily activity monitoring using a smartband, (3) diet diary and monitoring, (4) comorbidity monitoring including that for blood pressure and glucose level, (5) counseling by physicians, clinical nutritionists, and exercise therapists, and (6) health information. The smartband transmits data through the smartphone mobile gateway using Bluetooth, and the SAC application transmits data to the SAC platform using the internationally standardized HL7 protocol.

Personalized exercise programs

The most important component of the SAC system is a personalized exercise program. After baseline measurement, the 12-week personalized exercise program consisted of aerobic and resistance exercises based on the patient's level of physical activity and function for both the SAC and control groups. For patients at the 'inactive' level according to the International Physical Activity Questionnaire-short form (IPAQ-SF), 90 minutes of weekly exercise were added to their baseline activity. For patients at the 'minimally active' or 'Health-Enhancing Physical Activity (HEPA)-active' level, 150 minutes of weekly exercise were added. Patients with above average 2MWT scores were encouraged to set a goal of 65-80% of their maximal heart rate. For those with below average 2MWT scores, the target heart rate was set at 60-70% of their maximal heart rate. At the 6-week follow-up, if the patients achieved their target by more than half, 60 minutes of aerobic exercise were added weekly to the first prescribed aerobic exercise. Resistance exercises were composed of six major muscle group exercises individually chosen by the rehabilitation specialist. Patients were instructed to perform 2 sets of 10 repetitions for each exercise twice a week. Patients watched a video demonstrating the prescribed exercises using the SAC application and entered the number of sets performed. The entire SAC program was thus implemented using wearable sensors, the SAC application, and the SAC platform.

Intervention for the control group

Each patient in the control group received face-to-face education on the contents of the same SAC program and a paper brochure describing exercise suggestions of the SAC program. They were instructed to use a conventional pedometer to record the number of steps and minutes of physical activity performed and to record the number of resistance exercise sessions performed weekly. These records were checked by clinicians at the 6- and 12-week follow-up visits.

Outcome assessment

Several methods were used to measure changes in health status over time. Baseline and final assessments were composed of vital sign measurements (systolic and diastolic blood pressure and pulse rate), physical measurements (height, weight, body mass index, and body composition), cardiorespiratory endurance (2MWT), physical strength (handgrip strength test and 30-second chair stand test), SPPB, self-reported physical activity (based on the IPAQ-SF), and QoL measurements (EORTC-QLQ-C30 and EORTC-QLQ-PR25). Body composition was measured using a multi-frequency bioelectrical impedance analyzer, InBody S10 (InBody Co., Ltd., Seoul Korea) [16].

Statistical analysis

Sample size calculation with 90% power and a type-1 error rate of 5% showed that a total of 172 patients (86 in each group) were required to allow for a 10% drop-out rate. Statistical analysis was performed using IBM SPSS software, version 19.0 (SPSS, Inc., Chicago, Illinois, USA). Continuous variables are presented as means and medians (± standard deviation [SD]) and categorical variables as numbers and proportions. Differences in clinicopathologic characteristics were assessed using independent-sample and paired t-tests for continuous variables and chi-squared tests for categorical variables. Repeated-measures analysis of variance (ANOVA) was performed to assess differences between the two groups. Two-tailed *p*-values <0.05 were considered significant.

Results

Evidence before this study

The systematic search identified 172 references for initial screening. After reviewing titles and abstracts, 144 references were excluded, and 28 were included for full text review. However, all 28 were excluded due to the reasons listed in **Figure 3**. Our search yielded 1 clinical protocol for a randomized controlled trial [17], which was excluded because the related clinical outcomes could not be obtained. In the end, no studies met the criteria for inclusion in the systematic review.

Participant flow through the study

Initially, 206 patients were screened for eligibility and 34 were excluded. Therefore, 172 patients were enrolled; 86 were allocated to the SAC group and 86 to the control group. Twenty-four patients were lost to follow-up,

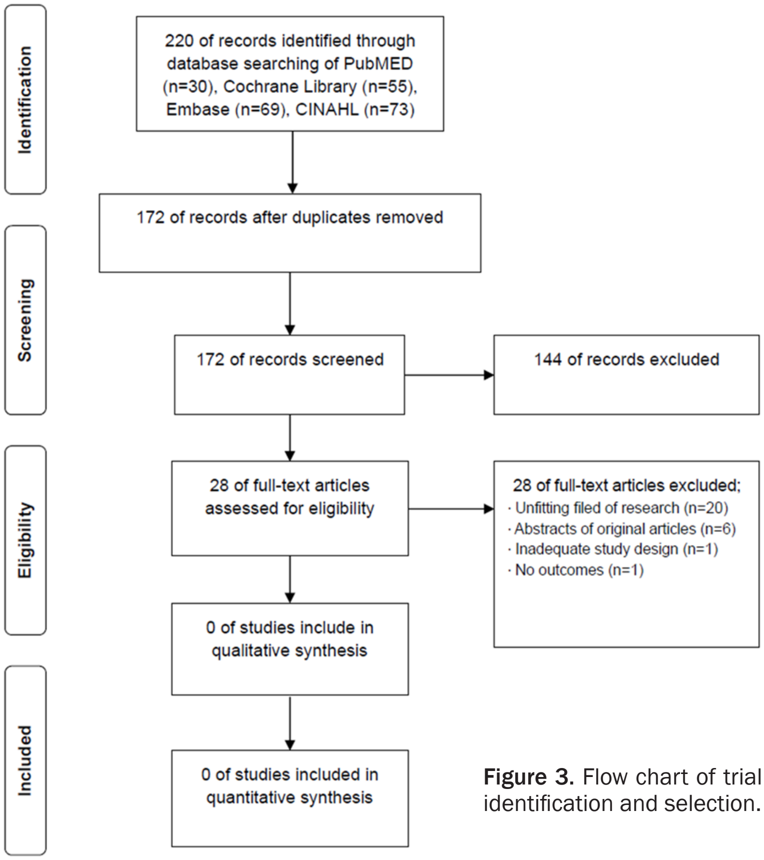

Figure 3. Flow chart of trial identification and selection.

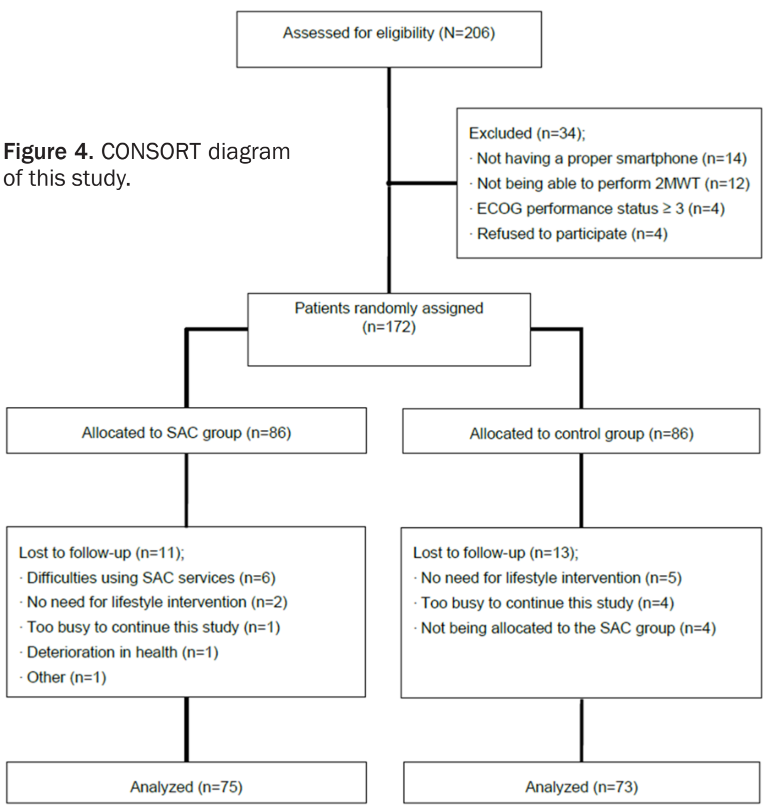

Figure 4. CONSORT diagram of this study.

and final assessments included 148 patients (**Figure 4**).

Baseline patient characteristics

Demographic and clinical characteristics of the patients are shown in **Table 2**. There were no significant differences in baseline characteristics between the control and SAC groups. Preoperative PSA levels were higher in the control group than in the SAC group, although the difference was not statistically significant (100.8 vs. 78.1 ng/mL, P = 0.502) and may be due to one patient who had an extremely high PSA level (2148.23 ng/mL) in the control group. The results of this patient were included because he did not meet the exclusion criteria and completed the 12-week study protocol.

Changes in physical function

The physical function test results are shown in **Table 3**. The baseline physical function was not different between the control and SAC groups. In the control group, cardiorespiratory endurance measured by the 2MWT and lower extremity strength measured by the 30-second chair stand test improved over time. In the SAC group, upper extremity strength measured by the hand grip strength test significantly increased along with cardiorespiratory endurance and lower extremity strength. Significant changes in 2MWT scores were observed over time (F = 77.751, p-value <0.001), and a significant interaction of group and time for 2MWT was observed (F = 4.299, p-value = 0.040). No

Table 2. Demographic and clinical characteristics of patients

Variables	Overall	Group		
		Control	Smart After-Care	*p*-value
Age (years)*	66.4, 66.0 (± 7.5)	66.5, 66.0 (± 8.2)	66.3, 65.0 (± 6.8)	0.848
BMI (kg/m^2)*	25.5, 25.1 (± 3.1)	25.7, 25.5 (± 2.9)	25.4, 24.7 (± 3.3)	0.466
Diabetes mellitus (%)	41 (23.8)	20 (23.3)	21 (24.4)	0.590
Hypertension (%)	98 (57.0)	51 (59.3)	47 (54.7)	0.526
Dyslipidemia (%)	49 (28.5)	22 (25.6)	27 (31.4)	0.405
Smoking (%)				0.429
Never-smoker	59 (34.3)	32 (37.2)	27 (31.4)	
Previous smoker	55 (32.0)	29 (33.7)	26 (30.2)	
Current smoker	58 (33.7)	25 (29.1)	33 (38.4)	
Alcohol (%)				0.937
None	130 (75.6)	64 (74.4)	66 (76.7)	
Yes	40 (23.3)	21 (24.4)	19 (22.1)	
Preoperative PSA (ng/mL)*	89.5, 22.4 (± 220.7)	100.8, 21.1 (± 285.9)	78.1, 23.2 (± 126.5)	0.502
Clinical T stage (%)				0.842
T1a	1 (0.6)	1 (1.2)	0 (0)	
T1b	0 (0)	0 (0)	0 (0)	
T1c	4 (2.3)	3 (3.5)	1 (1.2)	
T2a	9 (5.2)	5 (5.8)	4 (4.7)	
T2b	13 (7.6)	5 (5.8)	8 (9.3)	
T2c	37 (21.5)	18 (20.9)	19 (22.1)	
T3a	41 (23.8)	22 (25.8)	19 (22.1)	
T3b	55 (32.0)	27 (31.4)	28 (32.6)	
T4	11 (6.4)	5 (5.8)	6 (7.0)	
Clinical N stage (%)				0.273
N0	126 (73.3)	67 (77.9)	59 (68.6)	
N1	45 (26.2)	19 (22.1)	26 (30.2)	
Clinical M stage (%)				0.604
M0	143 (83.1)	72 (83.7)	71 (82.6)	
M1	28 (16.3)	14 (16.3)	14 (16.3)	
Biopsy Gleason score (%)				0.651
≤ 6	23 (13.6)	10 (11.9)	13 (15.3)	
7 (3+4)	31 (18.3)	13 (15.5)	18 (21.2)	
7 (4+3)	27 (16.0)	14 (16.7)	13 (15.3)	
≥ 8	88 (52.1)	47 (56.0)	41 (48.2)	
Treatment modality (%)				
Radical prostatectomy	100 (58.1)	45 (52.3)	55 (64.0)	0.122
Radiation therapy	90 (52.3)	46 (53.5)	44 (51.2)	0.760

*Values are expressed as mean, median (± SD). BMI, body mass index; PSA, prostate-specific antigen.

significant interaction of group and time for upper or lower extremity strength or SPPB scores was observed.

Changes in physical measurements

The results of physical measurements are shown in **Table 3**. The baseline physical measurements were not different between the control and SAC groups. No significant changes were observed in blood pressure, pulse rate, or body mass index over time in either group. A significantly increased body fat ratio was observed in both groups; however, decreased skeletal muscle mass was observed only in the control group. Significant changes in skeletal

Table 3. Changes in physical function and measurements

	Control group			After-Care group			p-value†
	Baseline	12 weeks	p-value*	Baseline	12 weeks	p-value*	
2MWT (m)	180.2 ± 23.6	188.6 ± 28.9	<0.001	180.7 ± 24.3	194.4 ± 23.9	<0.001	0.040
Grip strength							
Right (kg)	31.2 ± 8.7	31.9 ± 8.9	0.215	31.3 ± 6.9	32.2 ± 6.3	0.018	0.718
Left (kg)	31.1 ± 6.9	31.6 ± 7.3	0.379	31.7 ± 6.7	33.1 ± 6.2	0.001	0.287
30-second chair stand test (/30 s)	18.9 ± 21.1	21.1 ± 7.3	<0.001	19.7 ± 6.5	22.4 ± 6.8	<0.001	0.586
SPPB (score)	11.5 ± 1.0	11.6 ± 1.1	0.228	11.5 ± 1.0	11.7 ± 0.8	0.070	0.795
Vital sign							
sBP (mmHg)	134.1 ± 12.7	131.5 ± 13.2	0.093	133.3 ± 13.7	134.5 ± 13.8	0.529	0.241
dBP (mmHg)	77.7 ± 10.8	76.5 ± 8.4	0.349	77.9 ± 9.9	76.1 ± 8.9	0.111	0.114
PR (/min)	76.2 ± 10.5	76.1 ± 9.5	0.917	77.3 ± 11.1	78.4 ± 10.8	0.281	0.422
BMI (kg/m^2)	25.8 ± 2.8	25.9 ± 3.0	0.149	25.2 ± 2.7	25.4 ± 2.5	0.097	0.241
Body composition							
Skeletal muscle (kg)	28.9 ± 3.6	28.5 ± 3.6	<0.001	28.6 ± 3.4	28.5 ± 3.2	0.282	0.069
Body fat ratio (%)	28.0 ± 6.0	28.9 ± 6.5	0.001	27.5 ± 6.0	28.4 ± 5.3	0.005	0.862

Values are expressed as mean ± SD. *p-value between baseline and 12 weeks. †Group effect p-value analyzed by repeated measures ANOVA. 2MWT, 2-minute walking test; SPPB, short physical performance battery; sBP, systolic blood pressure; dBP, diastolic blood pressure; PR, pulse rate; BMI, body mass index.

muscle mass were observed over time (F = 11.803, p-value = 0.001) with a marginally significant interaction of group and time (F = 3.347, p-value = 0.069).

Changes in physical activity and quality of life

Weekly physical activity measured in metabolic equivalents using the IPAQ-SF significantly increased in both groups; however, no significant interaction of group and time was observed (**Table 4**).

The EORTC-QLQ-C30 revealed no significant changes in global health status over time in either group (**Table 4**). However, significant improvement in all functional scales, including social functioning (F = 29.814, p-value < 0.001), was noted after 12 weeks in both groups; there was significant interaction of group and time (F = 4.269, p-value = 0.040). No changes in symptom scales were noted over time in either group.

According to the EORTC QLQ-PR25, patients in the SAC group showed significant improvement in sexual functioning and urinary symptoms scales, while those in the control group showed improvement only in the urinary symptoms scale. A marginally significant interaction of group and time in the sexual functioning scale was observed (F = 3.905, p-value = 0.065), indicating the possibility for further improvement in sexual function after SAC.

Discussion

In this study, an appropriately prescribed lifestyle intervention in the form of either a paper brochure or an IoT-based platform effectively ameliorated a range of ADT-induced adverse effects in patients with PCa on ADT. Compared with a conventional lifestyle intervention, SAC led to: 1) significantly increased 2MWT scores, suggesting greater improvement in cardiorespiratory endurance; 2) tendency to suppress the loss of skeletal muscle mass, suggesting favorable effects on sarcopenia; and 3) significantly improved social functioning and tendency for improved sexual functioning. To the best of our knowledge, this is the first proof of the clinical efficacy of an IoT-based lifestyle intervention in patients with PCa on ADT.

There are several notable points in our study. First, IoT-based technologies represent an increasingly important mode of intervention in this era of coronavirus disease pandemic. Application of IoT-based technologies for healthcare service has been rapidly increasing, as has the number of published studies on the use of smartphone applications to improve patient's motivation and clinical efficacy in many chronic disease states, older adults [18], stroke survivors [19], and patients with chronic obstructive pulmonary disease [20]. To date, few studies have confirmed the usefulness of IoT-based lifestyle interventions in patients with cancer. Galiano-Castillo et al. conducted a

Table 4. Changes in physical activity and quality of life

Physical measurements	Control group			After-Care group			*p*-value†
	Baseline	12 weeks	*p*-value*	Baseline	12 weeks	*p*-value*	
Physical activity							
MET	1906.4 ± 2011.2	2909.2 ± 2893.5	0.006	1950.1 ± 2067.9	3404.9 ± 2912.0	<0.001	0.126
QLQ-C30							
Global health status	61.8 ± 20.7	61.4 ± 24.2	0.900	64.6 ± 23.9	68.9 ± 28.1	0.170	0.273
Functional scales							
Physical functioning	79.8 ± 16.0	89.6 ± 22.2	0.001	81.6 ± 13.8	94.3 ± 22.5	<0.001	0.497
Role functioning	80.5 ± 21.7	91.0 ± 25.6	0.001	85.1 ± 20.5	97.6 ± 23.5	<0.001	0.629
Emotional functioning	81.4 ± 17.1	89.9 ± 27.3	0.004	84.5 ± 18.6	97.3 ± 22.9	<0.001	0.284
Cognitive functioning	79.1 ± 15.3	87.2 ± 26.2	0.004	83.1 ± 14.2	94.4 ± 23.7	<0.001	0.440
Social functioning	81.8 ± 20.1	89.7 ± 27.3	0.017	81.2 ± 23.5	98.7 ± 24.1	<0.001	0.040
Symptom scales							
Fatigue	28.7 ± 17.7	26.3 ± 21.9	0.269	24.1 ± 18.7	22.9 ± 16.6	0.630	0.689
Nausea/vomiting	5.7 ± 11.4	4.5 ± 12.8	0.460	5.9 ± 8.3	4.4 ± 9.2	0.687	0.412
Pain	16.4 ± 22.6	17.9 ± 22.1	0.578	15.7 ± 18.0	10.6 ± 12.8	0.360	0.298
Dyspnea	15.4 ± 24.8	14.4 ± 20.3	0.718	14.3 ± 19.7	13.1 ± 17.5	0.709	0.981
Insomnia	26.9 ± 26.7	23.9 ± 30.0	0.321	26.0 ± 23.4	24.0 ± 25.9	0.521	0.252
Appetite loss	9.4 ± 18.2	11.4 ± 21.4	0.497	8.9 ± 13.4	6.8 ± 15.0	0.621	0.407
Constipation	20.9 ± 23.8	19.9 ± 27.9	0.734	19.7 ± 24.6	16.4 ± 22.5	0.293	0.592
Diarrhea	12.4 ± 19.1	11.9 ± 19.0	0.871	9.5 ± 15.4	7.9 ± 12.4	0.568	0.872
Financial difficulties	48.2 ± 28.7	50.0 ± 29.3	0.288	48.1 ± 28.5	47.2 ± 29.9	0.418	0.184
QLQ-PR25							
Functional scales							
Sexual activity	83.3 ± 24.9	86.8 ± 24.6	0.561	83.8 ± 20.7	81.5 ± 32.7	0.425	0.930
Sexual functioning	41.7 ± 28.4	39.1 ± 21.8	0.832	42.5 ± 29.2	49.6 ± 24.7	0.032	0.065
Symptom scales							
Urinary symptoms	37.0 ± 18.0	25.9 ± 17.5	0.023	40.1 ± 24.7	21.4 ± 18.3	0.017	0.374
Bowel symptoms	11.4 ± 10.1	8.8 ± 8.5	0.301	10.1 ± 7.9	6.0 ± 7.9	0.842	0.195
ADT-related symptoms	23.7 ± 16.3	24.8 ± 24.2	0.771	23.4 ± 13.4	19.2 ± 16.7	0.704	0.240
Incontinence aid	18.5 ± 24.2	14.8 ± 24.2	0.594	16.7 ± 17.8	16.7 ± 25.2	1.000	1.000

Values are expressed as mean ± SD. **p*-value between baseline and 12 weeks. †Group effect *p*-value analyzed by repeated measure ANOVA. MET, metabolic equivalents; ADT, androgen deprivation therapy.

randomized controlled trial involving 81 breast cancer patients [21] and found that the telerehabilitation group had significantly improved QoL scores; handgrip strength; abdominal, back, and lower body strength; and total fatigue when compared with the control group. Park et al. assessed the feasibility and efficacy of smartphone application-based pulmonary rehabilitation in patients with advanced lung cancer on chemotherapy and found that application-based pulmonary rehabilitation significantly improved exercise capacity and symptom scores and decreased psychological distress including depression and anxiety [22]. Consistent with these results, our study supports SAC as a promising alternative to conventional cancer rehabilitation minimizing barriers associated with distance, time, and cost [23].

Another interesting implication of our study is that SAC may increase the effectiveness of unsupervised home-based interventions. SAC resulted in improved cardiorespiratory endurance, sarcopenia, and QoL when compared with a conventional intervention. In the Trans-Tasman Radiation Oncology Group 03.04 Randomised Androgen Deprivation and Radiotherapy study, supervised exercise training in PCa survivors was more effective than unsupervised printed educational material in increasing cardiorespiratory fitness, physical function, muscle strength, and self-reported physical functioning [24]. Similarly, Ndjavera et al. reported that supervised exercise prevented adverse changes in cardiopulmonary fitness parameters such as peak O_2 uptake, ventilatory threshold, and fatigue [25]. Although the SAC program offers personalized goal setting, graded tasks, and instructions on how to perform exercises, it is basically an unsupervised home-based lifestyle intervention that does not need additional manpower for supervision. It is also free from potential confounders such as the fact that supervised programs are conducted in groups [22], which results in the sharing of common experiences and camaraderie [26].

This study has several limitations. First, a 12-week intervention period may be too short to achieve clinically significant outcomes in ADT. However, a recent meta-analysis suggested that application-based physical activity interventions were effective when their duration was 3 months or less when compared with longer interventions [27]. Further, in our study, 24 out of 172 patients (14.0%) dropped out during follow-up, potentially leading to incomplete data analysis and bias. This drop-out rate, however, might reflect an early interest in a novel application like SAC, with subsequent decline in interest. Technology-based healthcare interventions have the goal of keeping participants interested in using their software [28-30]. A systematic review of 83 web-based health interventions found that 50.3% of the participants fully adhered to the intervention [29]. Moreover, according to the online survey by the Consumer Health Information Corporation, 26% of the applications were downloaded and used only once, while 74% of users dropped out by the 10th use [31]. Several researchers have suggested ways to overcome this problem [29, 30]. Kelders et al. showed that increased interaction with a counselor, more frequent intended usage, more frequent updates, and more extensive dialogue ensured better adherence [29]. Ludden et al. suggested that design features such as personalization, ambient information, and use of metaphors are important to increasing adherence to web-based interventions [30]. Although we reviewed these suggestions and introduced several factors such as interaction with a counselor, personalized exercised program, and educational materials updated biweekly, more effort is needed to increase adherence and decrease drop-out.

In conclusion, this study demonstrates that SAC is an effective method for the management of ADT-related adverse effects, with positive effects on cardiorespiratory endurance, sarcopenic obesity, and health-related QoL. The use of IoT-based technology can potentially maximize the beneficial effect of lifestyle interventions in patients with PCa on ADT and more generally, in the field of cancer rehabilitation.

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Disclosure of conflict of interest

None.

Address correspondence to: Dr. Ji Youl Lee, Department of Urology, Seoul St. Mary's Hospital, School of Medicine, The Catholic University of Korea, 222 Banpo-daero, Seocho-gu, Seoul 06591, Republic of Korea. Tel: +82-2-2258-6227; Fax: +82-2-599-7839; E-mail: uroljy@catholic.ac.kr

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