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Effect of a Kinect-Based Exercise on Improving Job-Related Physical Fitness Tests for Korean Firefighters

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ABSTRACT

OBJECTIVES Firefighters play a critical role in high-temperature environments that demand substantial physical strength for efficient job performance. However, South Korean firefighters face challenges in maintaining optimal fitness levels due to limited opportunities for exercise. Factors that contribute to this issue include shift work, frequent dispatches, and the absence of exercise instructors.

METHODS At total of 20 male Korean firefighters were divided into an exercise group (EG) and a control group (CG) with ten participants each. The EG group underwent an 8-week exercise intervention at a fire academy in Busan using a kinect-based exercise device called Virtual Mate (VM), while the CG group maintained their regular lifestyle without any additional exercise. Pre- and post-assessments were conducted, including the Candidate Physical Ability Test (CPAT), a physical fitness evaluation commonly used for firefighting duties in North America, the Korea Firefighter Performance Battery (KFPB), which is a modified version of CPAT, and basic physical fitness tests. The effect of exercise was analyzed using statistical methods, including repeated measures analysis of variance and paired t-tests.

RESULTS Significant group-by-time interactions were observed for CPAT completion time (p = .004) and KFPB completion time (p = .012). After 8 weeks of exercise, the EG demonstrated a significant decrease in CPAT completion time (543.7 ± 93.0 sec vs. 500.8 ± 64.1 sec, p = .004) and KFPB completion time (584.1 ± 47.8 sec vs. 525.3 ± 16.2 sec, p = .001), while the CG did not show significant changes. In terms of basic physical fitness, only in EG, number of sit-ups performed in one minute significantly increased (p < .001)

CONCLUSIONS The Kinect-based exercise device, VM, proves to be a valuable solution for addressing the practical challenges faced by Korean firefighters, ultimately enhancing their physical fitness.

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Introduction

Firefighting demands a high degree of physical strength owing to strenuous job tasks (e.g., equipment transportation, hose pulling, and rescue operations) in high-temperature environments [1,2]. Previous research has consistently reported that firefighters' heart rate reaches its maximum during firefighting tasks while wearing safety equipment [3-5]. Furthermore, a consistent increase in heart rate and oxygen uptake has been observed during both actual firefighting activities and simulation training [6-8]. This indicates that firefighting tasks involve high-intensity activities. To safely perform demanding firefighting tasks, various physical abilities such as muscular endurance, power, aerobic and anaerobic capacity are essential [9-11]. Particularly, there is a close association between cardiorespiratory fitness and a significant increase of 3 mL/kg/min in maximum oxygen uptake, which can reduce the risk of injury by as much as 14% [12]. Therefore, it is recommended to achieve a cardiorespiratory fitness level of approximately 40-45 mL/kg/min in maximum oxygen uptake for safe firefighting operations [13-15].

In many countries, regular assessments of firefighting job-related and basic physical fitness are conducted to ensure staff maintain high levels of physical readiness. Among these evaluations, the collaborative efforts of the International Association of Fire Chiefs and the International Association of Firefighters led to the development of the Candidate Physical Ability Test (CPAT) for firefighter recruitment [16]. The CPAT has been extensively studied as a physical fitness assessment tool appropriate for assessing the capacity to perform firefighting duties [17,18]. Individuals who successfully passed the CPAT demonstrated significantly superior levels of maximum oxygen intake and grip strength compared to those who did not pass [1]. These results affirm that the CPAT serves as a comprehensive assessment of the essential physical fitness components necessary for effective performance in firefighting duties. Additionally, basic physical fitness tests (e.g., grip strength, sit-ups, standing long jumps, and shuttle runs) have been widely used [19]. Nowadays, the Korean Firefighter Performance Battery (KFPB), a recently developed assessment that simplifies the CPAT, is gaining recognition as a valuable physical fitness evaluation specifically tailored to firefighting duties [20]. The KFPB exhibits higher validity and reliability compared to the CPAT, while also providing notable advantages such as its compact size (1/100 of CPAT), lower manufacturing costs (1/30 of the cost), and excellent portability [20].

The physical fitness level of Korean firefighters, as assessed by the CPAT and basic physical fitness tests, demonstrated a low level [21,22]. The CPAT completion times exceeded the passing standard by an average of 1 min and 46 sec [21], and the grip strength in the basic physical fitness test was found to be lower compared to Canadian, American, and German firefighters [22]. This indicates that Korean firefighters do not meet the optimal levels of muscular strength, muscular endurance, and cardiorespiratory fitness [23,24], which are essential for the performance of firefighting activities. This can hinder the safe and efficient execution of firefighting tasks [24]. Therefore, it is crucial for Korean firefighters to improve their physical fitness through regular training. Previous studies have identified low exercise participation rates as a key contributing factor to decreased physical strength among Korean firefighters. Shockingly, less than 50% of Korean firefighters reported engaging in moderate-intensity exercise for 150 min or more per week [25].

Factors influencing inadequate physical fitness among Korean firefighters include shift work patterns, frequency of emergency dispatches, absence of an exercise instructor, and limitations related to facilities and spaces [25]. One possible solution to address these issues is the use of a kinect-based exercise device, which employs a camera to effectively track body joints and provide real-time feedback on exercise movements. It has the potential to substitute the role of exercise instructors and can be accessed round-the-clock, irrespective of the number of emergency dispatches and work shift types. The technology-driven kinect-based exercise also device facilitates the comprehensive development of all major muscle groups through a wide range of exercise movements. Meanwhile, constraints of limited facilities and space can be overcome by substituting kinect-based exercise devices. Previous studies have demonstrated the effectiveness of kinect-based exercise devices in providing efficient

Figure 1. Virtual Mate Device.

exercise therapy for older individuals and patients [26-28]. However, there is currently a lack of studies examining the impact of utilizing kinect-based exercise devices specifically for firefighters, who typically exhibit a higher level of physical strength than the general population.

In this study, Korean firefighters were assigned to either an exercise group (EG) or a control group (CG), and an 8-week exercise program targeting firefighting job-related physical fitness was implemented using kinect-based exercise device. CPAT, KFPB, and basic physical fitness tests served as measures to assess the effectiveness of the interventions.

Methods

Participants

Twenty male Korean firefighters were recruited for this study. The participants were divided into an EG (n = 10) and a CG (n = 10). The risk of physical activity was checked through the revision of the physical readiness questionnaire (Physical Activity Readiness Questionnaire and YOU+) before physical fitness evaluation [29]. The EG engaged in exercise using the Virtual Mate (VM, Virtual mate, My Benefit Co., Ltd., Seoul, Rep. of Korea), a kinect-based exercise device known for its high level of validity and reliability [30], three days per week over an eight-week period. In addition, the EG utilized a heart rate monitor (Polar H10, Polar Electro Co., Ltd., Kempele, Finland) to monitor their heart rate during exercise. In contrast, the CG was instructed to maintain their regular lifestyles without incorporating any additional exercise during the intervention period. Pre- and post-physical assessment tests were conducted on all participants to determine the effects of exercise training after the intervention. Prior to the commencement of the study, written informed consent was obtained from all participants, and the study protocol was approved by the Institutional Review Board of Pusan National University (PNU IRB/2021_50_HR).

Exercise program

During the 8-week exercise intervention using the VM, the EG participants followed a specific training program. They engaged in 30-minute exercise sessions, three days a week, as illustrated in <Figure 1>. The VM exercise program was developed based on the CPAT guidelines and consisted of 14 exercises [31]. Each exercise was performed for 60 seconds, followed by a 15-second recovery period. The program also included a 5-minute warm-up and cool-down routine. <Table 1> shows the VM exercise training programs for weeks 1-4, while <Table 2> displays the programs for weeks 5-8. Notably, the workload for exercise selection, such as two-arm dumbbell rows, shoulder presses, straight deadlifts, deadlifts, and dumbbell floor presses, was increased by approximately 20%. For instance, during weeks 1-4, 5kg dumb-

Table 1. Korean firefighter fitness program for weeks 1-4.

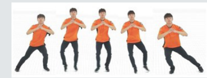
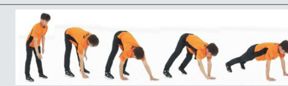
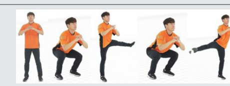
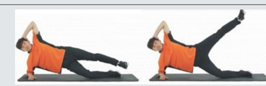
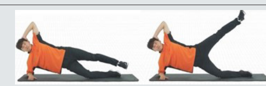
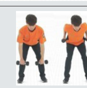
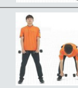
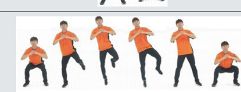
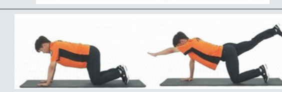
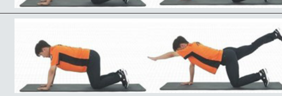
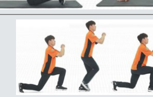
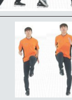
Order	Type	Time (sec)	Exercise
Warm-up	Dynamic stretching	300	
Main Exercise	Side step	60	
	Push up	60	
	Arm walking	60	
	Running man kick (right)	60	
	Running man kick (left)	60	
	Squat side kick	60	
	Plank	60	
	Beginner side plank raise (right)	60	
	Beginner side plank raise (left)	60	
	Two arm dumbbell row	60	
	Shoulder press	60	
	Straight deadlift	60	
	Two hop squat	60	
	Bird dog (right)	60	
	Bird dog (left)	60	
	Pendulum lunge (right)	60	
	Pendulum lunge (left)	60	
	High knee	60	
Cool Down	Static stretching	300	

Table 2. Korean firefighter fitness program for weeks 5-8.

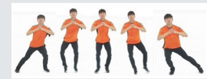
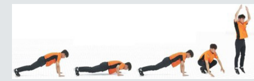
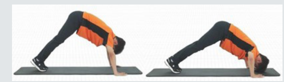
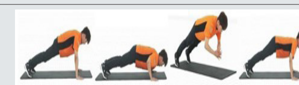
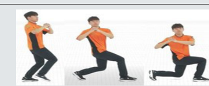
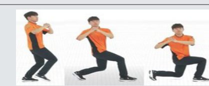
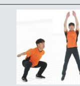
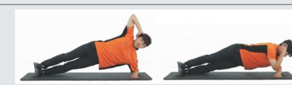
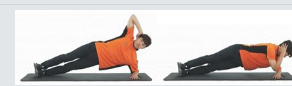
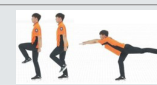
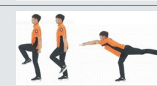
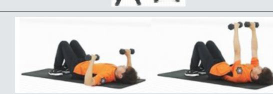
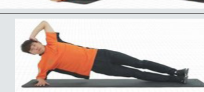
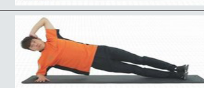
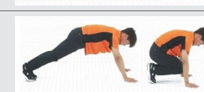
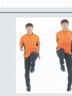
Order	Type	Time (sec)	Exercise
Warm-up	Dynamic stretching	300	
Main Exercise	Side step	60	
	Full burpee	60	
	Pike push up	60	
	clapping push up	60	
	Twist lunge (right)	60	
	Twist lunge (left)	60	
	Jump squat	60	
	Side plank oblique twist (right)	60	
	Side plank oblique twist (left)	60	
	Warrior balance (right)	60	
	Warrior balance (left)	60	
	Pop squat	60	
	Deadlift	60	
	Dumbbell floor press	60	
	Side plank (right)	60	
	Side plank (left)	60	
	Half burpee	60	
	High knee	60	
Cool Down	Static stretching	300	

Table 3. Baseline characteristics of participants.

Variables	EG (n = 10)	CG (n = 10)	*p* [a]
Age (years)	36.80 (5.63)	40.10 (8.03)	.302
Height (cm)	174.58 (3.77)	174.50 (4.40)	.966
Weight (kg)	77.10 (6.94)	77.32 (8.27)	.949
Body mass index (kg/m^2)	25.27 (1.79)	25.39 (2.45)	.902
Body fat (kg)	16.04 (3.20)	16.08 (4.06)	.981
Skeletal muscle mass (kg)	34.50 (3.63)	34.78 (3.33)	.860

Data are expressed as mean (standard deviation). EG, exercise group; CG, control group. [a] Independent t-test

bells (10kg total) were used, whereas weeks 5-8 involved the use of 6kg dumbbells (12kg total).

Body composition

Weight (kg), body fat (kg), and skeletal muscle mass (kg) were assessed using bioelectrical impedance analysis (Inbody620, Inbody Co., Ltd., Seoul, Rep. of Korea). Body mass index (BMI) was calculated using weight (kg) and height (cm). There were no significant differences in age, weight, height, BMI, body fat mass, and skeletal muscle mass between the EG and CG at baseline <Table 3>.

Candidate physical ability test

The CPAT comprises eight consecutive sections: Stair Climbing, Hose Dragging and Pulling, Equipment Carrying, Ladder Raising and Extending, Forced Entry, Search, Rescue, and Ceiling Breaking and Pulling. The test is performed while wearing a weighted vest, and the objective is to complete all sections within 620 sec to pass the test [19]. During the stair climbing section, participants utilize step-mill equipment to ascend the stairs at a rate of 60 steps per minute for 3 min, with an additional 10 kg weight applied solely during this section. In the hose dragging and pulling section, participants carry a fire hose weighting approximately 10 kg, with a length of 60 m and a diameter of 44 mm. They move the drum 22.9 m, rotate it 90°, and proceed to move an additional 7.6 m. Within a designated area measuring 1.52 m in length and 2.13 m in width, participants kneel with one knee on the floor and pull the hose for a distance of 15.24 m. The equipment carrying section entails extracting two pieces of equipment from a cabinet, gripping one in each hand, and transporting them a distance of 91.4 m to return them inside the cabinet. In the ladder raising and extending section, participants begin by positioning a ladder against a wall from its initial floor placement. They then extend the ladder to its full length before repositioning it. The forced entry section involves striking a measuring instrument with a 4.54 kg hammer until a buzzer signal is triggered. In the search section, participants navigate through a maze-like tunnel with dimensions of 91.44 m in height, 121.92 m in width, and 19.51 m in length, while contending with restricted lighting conditions. During the Rescue section, participants employ a harness to lift a 50 kg dummy and transport it a distance of 42.6 m. Finally, the ceiling breaking and pulling section comprises three repetitions of lifting a 27.2 kg ceiling using a 1.8 m bar, followed by five repetitions of lowering a 36.3 kg ceiling. Participants alternate between pushing and pulling movements, completing a total of four cycles.

Korean firefighter performance battery

The specific method of performing the KFPB involves consecutively performing all eight sections of the step box up and down, walking and sitting dumbbell row, dumbbell walking, arm walking and dumbbell push press, side kettlebell swing, side knee-up and full plank posture, barbell sumo squats, and barbell push and barbell rows while wearing a weighted vest [20]. The KFPB evaluation criteria are categorized into four levels. The first level ranges from 441 sec to 497 sec, the second level ranges from 498 sec to 521 sec, the third level ranges from 522 sec to 599 sec, and the fourth level ranges from 560 sec to 751 sec. In the step box exercise, participants wore an additional weight of 10 kg specifically for this section. They performed step-ups and step-downs on a 30 cm high step box for a duration of 3 min, following a metronome set at a speed of 120 beats per minute. During the walking and seated dumbbell row exercise, participants walked in place with a 10 kg dumbbell placed on one shoulder. They then held a 5 kg dumbbell in both hands and assumed a seated position with one knee on the floor. They performed a total of 30 arm pulls, alternating between each arm. In the walking with dumbbell section, participants engaged in stationary walking exercise while holding a pair of 13 kg dumbbells in each hand. The arm walking and dumbbell push press sections involved starting from a standing position and performing a floor touch exercise by placing hands on the floor, lowering the chest until it touched the floor, and returning to a standing position twice. Participants then held a pair of 5 kg dumbbells in each hand and completed 20 shoulder presses, alternating between arms. In the side kettlebell swing section, participants performed 10 swings with a 4.54 kg kettlebell, starting from the floor on the outside of one foot and swinging it up to the top of the opposite shoulder. During the side knee-up with full plank position exercise, participants performed 40 repetitions of alternating raising and lowering their body until their right knee touched their right elbow in the same direction. The barbell sumo squat section involved participants performing 10 repetitions of squats with a 30 kg barbell placed on the floor. For the barbell push press and barbell row segments, participants executed three shoulder-level overhead lifts using a 9 kg barbell in each hand. Additionally, they performed five rows using a 24 kg barbell. These two movements were alternated for a total of four cycles.

Basic physical fitness test

The evaluation of basic physical fitness included muscle strength, agility, flexibility, and muscular endurance, which are currently regularly conducted by firefighters in Korea. Initially, the grip strength of the dominant hand was measured. Next, participants performed a standing long jump to assess their agility. The third test involved a sit-and-reach exercise to evaluate flexibility. Finally, participants performed sit-ups to assess their muscular endurance.

Statistical analysis

Statistical analysis was performed using SPSS version 25.0, and the mean and standard deviation of all data were calculated. Repeated-measures analysis of variance was performed with a group variable (EG and CG) as a between-subject factor and a time variable (pre- and post-intervention) as a within-subject factor to evaluate the interaction. Paired t-tests were used to compare the mean difference between the pre- and post-exercise values in each group. Independent t-tests were performed to compare the baseline differences between the EG and CG. To confirm the effect of the intervention, the ES was calculated. The level of significance was set at $p < .05$.

Results

Participant characteristics

The changes in body composition after 8 weeks of exercise are shown in <Table 4>. Both groups showed no significant decreases in body weight, body fat mass, BMI and skeletal muscle mass. Also, there were no significant interactions between the groups.

Heart rate response of exercise

The HR response of the participants in each week is shown in <Table 5>. During the eighth week of the study, a decrease was observed in heart rate during exercise ($HR_{exercise}$) and the percentage of maximum heart rate ($\%HR_{max}$) estimated by a formula [32].

Job-related physical fitness test in firefighting occupations

CPAT time at baseline were 543.7 ± 93.0 sec and 545.1 ± 47.0 sec in the EG and CG, respectively, and there was no statistical difference between the groups. After 8 weeks of exercise, the EG showed a significant decrease in CPAT complete time to 500.8 ± 64.1 sec (p = .004), while the CG did not <Figure 2>. There was a significant interaction between the groups in CPAT completion time (p = .004, η^2 = 0.371).

KFPB time at baseline were 584.1 ± 47.8 sec and 595.1

Table 4. Comparative analysis of characteristics of participants.

Variables	Group	Pre	Post	*t*-test [a]			ANOVA [b]		
				t	*p*	ES [c]	F	*p*	ES [d]
Weight (kg)	EG	77.10 (6.94)	76.77 (6.39)	0.438	.672	2.382	0.487	.494	0.026
	CG	77.32 (8.27)	77.63 (7.79)	-0.593	.568	1.653			
Body mass index (kg/m²)	EG	25.27 (1.79)	25.18 (1.60)	0.351	.734	0.811	0.421	.525	0.023
	CG	25.39 (2.45)	25.50 (2.41)	-0.644	.536	0.540			
Body fat (kg)	EG	16.04 (3.20)	16.07 (3.18)	-0.062	.952	1.521	0.547	.469	0.029
	CG	16.08 (4.06)	16.58 (4.19)	-1.204	.259	1.313			
Skeletal muscle mass (kg)	EG	34.50 (3.63)	34.26 (3.73)	0.759	.467	1.000	0.000	1.000	0.000
	CG	34.78 (3.33)	34.54 (2.86)	0.908	.387	0.8356			

Values are presented as the mean (standard deviation). ES, effect size; EG, exercise group; CG, control group. [a] Paired t-test; [b] Repeated-measures ANOVA; [c] Cohen's d; [d] Partial ETA squared.

Table 5. Descriptive statistics of heart response.

Period	Week	$HR_{exercise}$ (beats/min)	% HR_{max} (%)
1 – 4 weeks	Week 1	145.2 (10.6)	79.5 (5.1)
	Week 2	144.9 (9.9)	79.4 (5.0)
	Week 3	142.4 (11.9)	78.0 (6.1)
	Week 4	138.2 (95.0)	75.7 (8.0)
5 – 8 weeks	Week 5	143.1 (9.3)	78.4 (4.8)
	Week 6	139.3 (11.8)	76.3 (6.3)
	Week 7	137.4 (11.9)	75.3 (6.5)
	Week 8	140.9 (12.1)	77.2 (± 6.5)

Data are expressed as mean (standard deviation).

± 67.4 sec in the EG and CG, respectively, and there was no statistical difference between the groups. After 8 weeks of exercise, the EG showed a significant decrease in KFPB time to 525.3 ± 16.2 sec (p = .001), whereas the CG did not <Figure 2>. There was a significant interaction between the groups and an increase in KFPB completion time (p = .012, η^2 = 0.301).

Basic physical fitness test

Fitness tests were conducted at baseline for both the EG and CG, and the results showed no statistically significant differences between the two groups. After eight weeks of exercise, among the basic fitness tests, the EG showed an improvement of approximately 10% only in sit-ups. There was a significant interaction between groups in sit-up and showed significant improvement over time <Table 6>.

Discussion

This study aimed to propose a strategy for enhancing the physical strength of Korean firefighters who experience lower physical fitness levels due to limited exercise opportunities caused by shift work, frequent dispatches, and a lack of exercise instructors. To address these challenges, an exercise intervention utilizing a kinect-based exercise device was conducted over a period of eight weeks, and its impact on the physical strength of domestic firefighters was examined. The effectiveness of the exercise interventions was assessed through physical fitness and firefighting assessments.

Surprisingly, the exercise participation rate was exceptionally high (99%), and no cases of exercise discontinuation or injury were reported. This is because VM provides convenient access and flexibility to exercise equipment, allowing

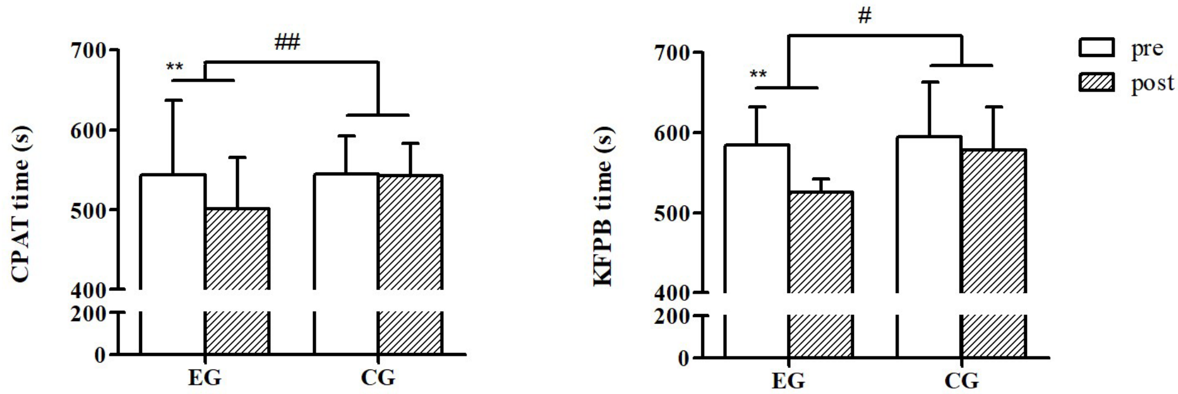


Figure 2. Comparative Analysis of Job-Related Physical Fitness Test in Firefighting Occupations.

CPAT, candidate physical ability test; KFPB, Korean firefighter performance battery; EG, exercise group; CG, control group; ** Significant difference pre vs. post at p < .01; # Significant interaction between the group and the change in KFPB time at p < .05; ## Significant interaction between the group and the change in CPAT time at p < .01.

Table 6. Comparative analysis of basic physical fitness test.

Variables	Group	Pre	Post	*t*-test [a]			ANOVA [b]		
				t	*p*	ES [c]	F	*p*	ES [d]
Hand grip strength (kg)	EG	50.64 (6.99)	52.18 (3.06)	1.021	.334	0.323	0.063	.805	0.003
	CG	52.03 (5.49)	53.10 (7.99)	0.963	.361	0.304			
Sit-up (reps)	EG	45.20 (5.33)	50.30 (4.79)	9.000	<.001	2.846	22.300	<.001	0.553
	CG	44.70 (6.70)	45.20 (6.23)	0.631	.544	0.200			
Sit and reach (cm)	EG	14.90 (7.92)	17.79 (6.81)	2.689	.025	0.850	5.304	.033	0.228
	CG	17.02 (4.58)	17.10 (4.01)	0.138	.893	0.044			
Standing long jump (cm)	EG	214.60 (21.82)	218.90 (17.43)	0.872	.406	0.276	0.396	.537	0.022
	CG	226.80 (19.05)	227.60 (20.04)	0.310	.763	0.098			

Values are presented as the mean (standard deviation). ES, effect size; EG, exercise group; CG, control group. [a] Paired t-test; [b] Repeated-measures ANOVA; [c] Cohen's d; [d] Partial ETA squared.

firefighters to perform physical activities at their own convenience. Additionally, schedule flexibility allows managers to easily incorporate exercise sessions into firefighter shift schedules. The exercise program implemented on the VM demonstrated a high-intensity aerobic workout, with an intensity ranging from 77.2-79.5% of HR_{max} [33]. Considering that the intensity of firefighting tasks falls within the range of 79-88% of maximum heart rate [35,36], it can be concluded that the exercise program intensity in this study is suitable. The exercise program in this study was specifically designed to meet the required fitness levels of firefighters and promote significant improvements in cardiovascular function [34]. Furthermore, since cardiovascular diseases account for nearly half of the major causes of firefighter fatalities, the implementation of such a program could potentially reduce the associated risks [37,38]. Consequently, The Kinect-based exercise program employed in this study proved to be an effective solution for Korean firefighters, as it provided suitable exercise intensity to maintain their required fitness levels and addressed the difficulties in maintaining regular exercise routines.

The CPAT is a firefighting-related physical fitness assessment that requires completing eight consecutives' sections within 620 sec. This demonstrates that the CPAT accurately reflects the essential fitness components required for firefighters, including cardiorespiratory endurance, muscular strength, and muscular endurance. In this study, the baseline CPAT performance times for the EG and CG were 543.7 ± 93.0 sec and 545.1 ± 47.8 sec, respectively. Both groups successfully completed the CPAT within the designated timeframe of 620 sec, indicating that they possessed an appropriate level of physical fitness for firefighting duties. In contrast, a previous study conducted with Korean firefighters reported a CPAT performance time of 726.6 ± 84.6 sec, indicating a failure to meet the CPAT criteria [21]. The significant difference in CPAT performance times between this study and those of a previous study despite both being conducted with Korean firefighters, can be attributed to differences in participant characteristics [21]. While the previous study focused on newly recruited firefighters, this study included firefighters with an average work experience of approximately nine years. As the CPAT is designed based on firefighting tasks, firefighters with more experience are likely to be more familiar with the specific movements required in CPAT, resulting in faster performance times. It is important to highlight that after an 8-week exercise intervention using the VM, the experimental group showed an approximate 8% improvement in CPAT performance time.

In the KFPB development study, specific evaluation criteria were established for each grade: grade 1 (441-497 sec), grade 2 (498-521 sec), grade 3 (522-599 sec), and grade 4 (560-751 sec) [20]. Initially, both the EG and CG participants in this study were categorized as grade 4. However, following the 8-week training period, the EG group exhibited significant progress, achieving grade 3 with an impressive 11% enhancement in their performance records. These findings provide additional evidence supporting the beneficial impact of the exercise program utilizing the VM.

However, in the current regular basic physical fitness assessments conducted on Korean firefighters, only sit-ups showed improved results after exercise intervention using VM. This can be attributed to the fact that the exercise intervention program did not include exercise movements that specifically targeted handgrip strength and sit-and-reach. Additionally, although the experimental group exhibited an increase in the absolute value of the standing long jump, it was not statistically significant, suggesting that a longer intervention period than the one used in this study may be necessary to demonstrate improvement. However, even if significant improvements were not observed in most items in the basic fitness assessment, it is difficult to conclude that exercise interventions using VM are ineffective for firefighters. The reason for this is that, as a result of evaluating the current Korean firefighters' physical fitness test criteria on a scale of 1 to 10, the CG group showed a slight improvement in all items, while the EG group showed remarkable progress. Specifically, grip strength improved from 3 points to 4 points, sit-ups improved from 4 points to 9 points, and forward bends improved from 0 points to 2 points. Nevertheless, the results of firefighting tasks (hose deployment, forced entry, salvage, lifesaving, stair climbing, etc.) and basic physical fitness indicators (grip strength, sit-up, forward bending, long jump in place, etc.) showed significant but low to moderate correlations (r=.378-.624) [39]. Therefore, it seems unrealistic to evaluate the firefighting job ability only with the results of the basic physical fitness test. This is because, as proven in numerous previous studies, as demonstrated in numerous previous studies, the physical fitness level required for firefighting activities involves complex physical abilities that are difficult to measure solely through basic fitness assessments [40,41]. Furthermore, in a suitability survey of fitness assessments conducted on domestic firefighters, 44% of current firefighters and 57% of new recruits reported that simple basic fitness assessments were unsuitable for evaluating firefighter fitness [42], lending support for the argument that it is difficult to claim that the exercise program based on firefighting movements in this study was ineffective.

It has been reported that firefighters with obesity perform firefighting tasks 70-80% slower compared to those with appropriate body composition levels [43]. Furthermore, obesity has been identified as a significant risk factor for subsequent disability, with each unit increase in BMI associated with a 5% increase in the risk of job disability [44,45]. Evidence also suggests that firefighters with high BMIs have impaired vascular function and a higher risk of cardiovascular disease [46]. The BMI of the participants in this study was approximately 25 kg/m^2, within the normal range and comparable to firefighters abroad [47]. While they currently maintain appropriate body composition, further efforts are necessary to ensure smooth and safe job performance. In this study, exercise was implemented without imposing dietary restrictions. However, according to the recommendations of the ACSM, for clinically significant weight loss without dietary restrictions, an exercise program using 1200-2000 kcal of energy per week and engaging in moderate to high-intensity exercises for 150-250 min is advised [48]. Previous studies have shown an 8% weight loss over 12 weeks with daily energy expenditure of 700 kcal through exercise [49]. In this study, although high-intensity exercise was conducted, the duration of 90 min per week might have limited the potential for improvements in body composition without dietary restrictions.

This study demonstrated that the use of a technical method utilizing a kinect-based device can enhance the effectiveness of improving the physical fitness of Korean firefighters by eliminating realistic obstacles. These findings can serve as foundational data for evaluating firefighting job-related physical fitness among Korean firefighters through assessments such as CPAT and KFPB. However, the modified CPAT used in this study had slightly reduced weights (approximately 10%) in specific sections, such as rescue, ceiling breach, and pulling, compared to the original CPAT. This adjustment was made based on a pilot test conducted prior to the experiment, which revealed that completing the CPAT with the original intensity was not feasible. It is important to note that physical activity, apart from diet and intervention, could not be restricted, which remains a limitation of the study. Moreover, the low proportion of female firefighters in Korea (9.4%) hinders the generalizability of the study's results. Further research focusing on the recruitment and physical fitness of female firefighters is needed [50].

Conclusions

In this study, Korean firefighters who face challenges (e.g., irregular physical activity due to shift work, frequent dispatches, and lack of exercise guidance) engaged in exercise using a kinect-based exercise device to examine its impact on firefighting job-related physical fitness. The findings revealed 8% and 11% improvements in the CPAT and KFPB, respectively. These results indicate that using VM for exercise is beneficial for enhancing firefighters' physical strength.

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Conflicts of Interest

The authors declare no conflicts of interest.

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