SICOM & AOCO 2024
SOMS International Conference on Obesity & Metabolism in conjunction with Asia-Oceania Conference on Obesity

Kinect-Based Mixed Reality Workouts: Enhancing Physical and Metabolic Health

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Hosted by SOMS Society for Korean Obesity and Metabolism Studies
Co-Hosted by Asia Oceania Association for the Study of Obesity
HESL Health & Exercise Science Laboratory

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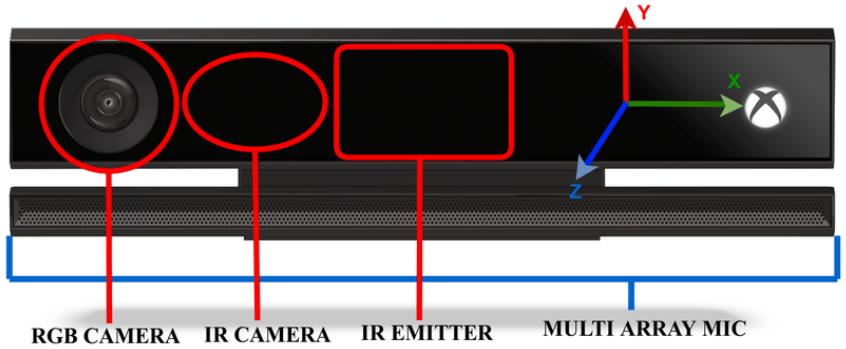
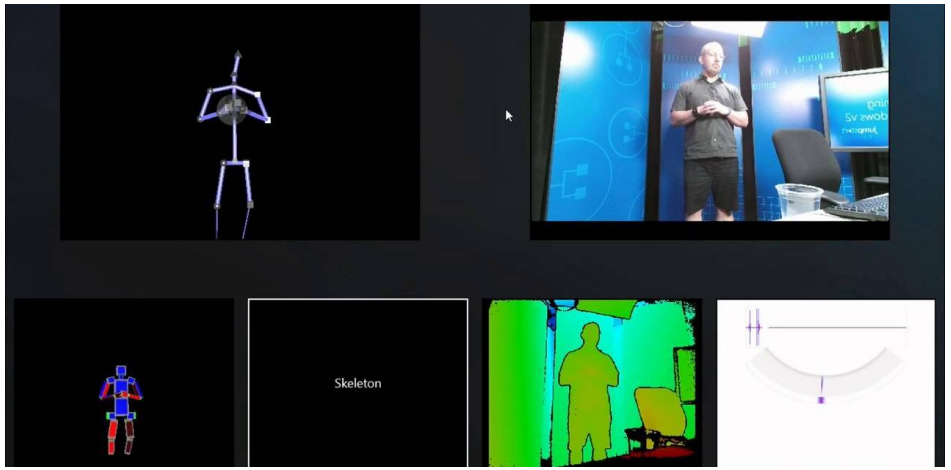
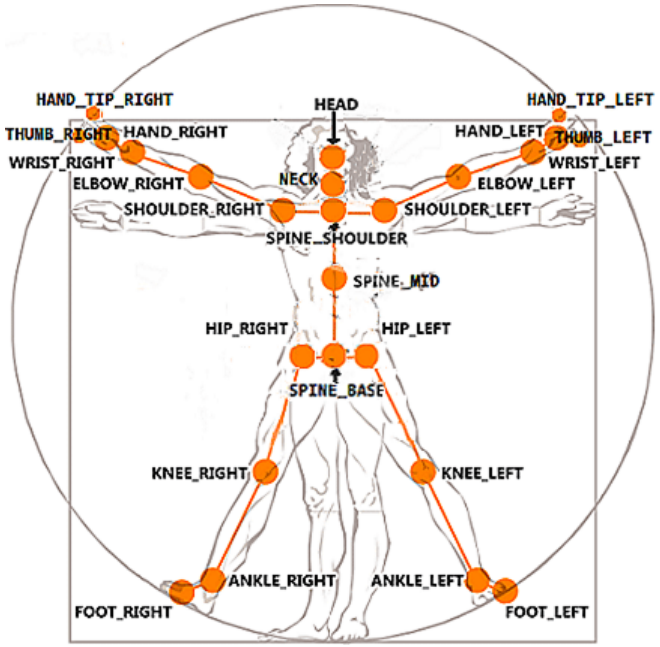
What is a Kinect-based Mixed Reality (KMR) Device?

Motion Sensing Camera: Kinect V2

Part of Kinect-based mixed reality device







- **Kinect** is a Motion detecting sensor devel oped by **Microsoft**
- Detect 25 joint of the body
- Using X, Y, Z axis

Otte K et al. *PLoS One*. 2016; 11(11): e0166532
Mateo F et al. *Sensors (Basel)*. 2018; 18(8).

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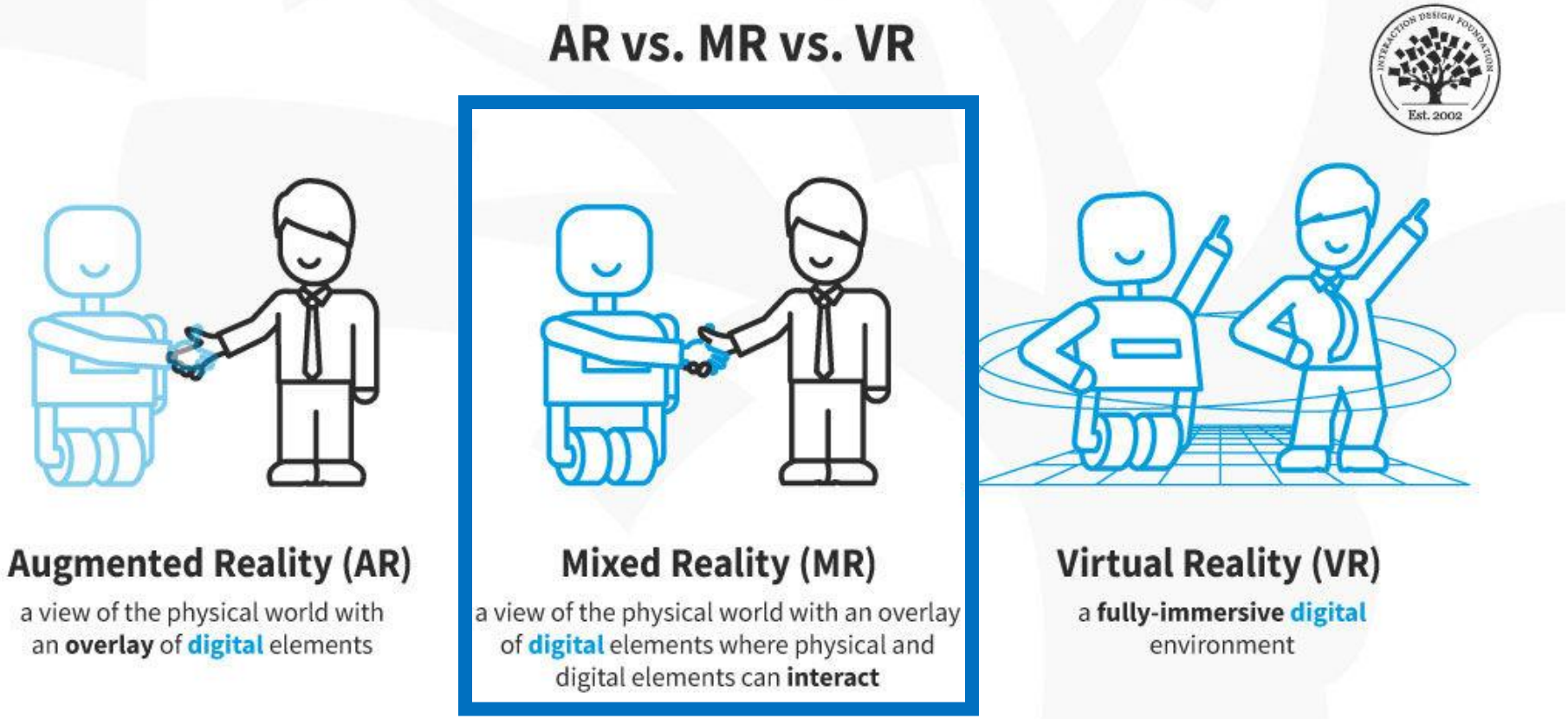
Mixed Reality Environment

Part of Kinect-based mixed reality device

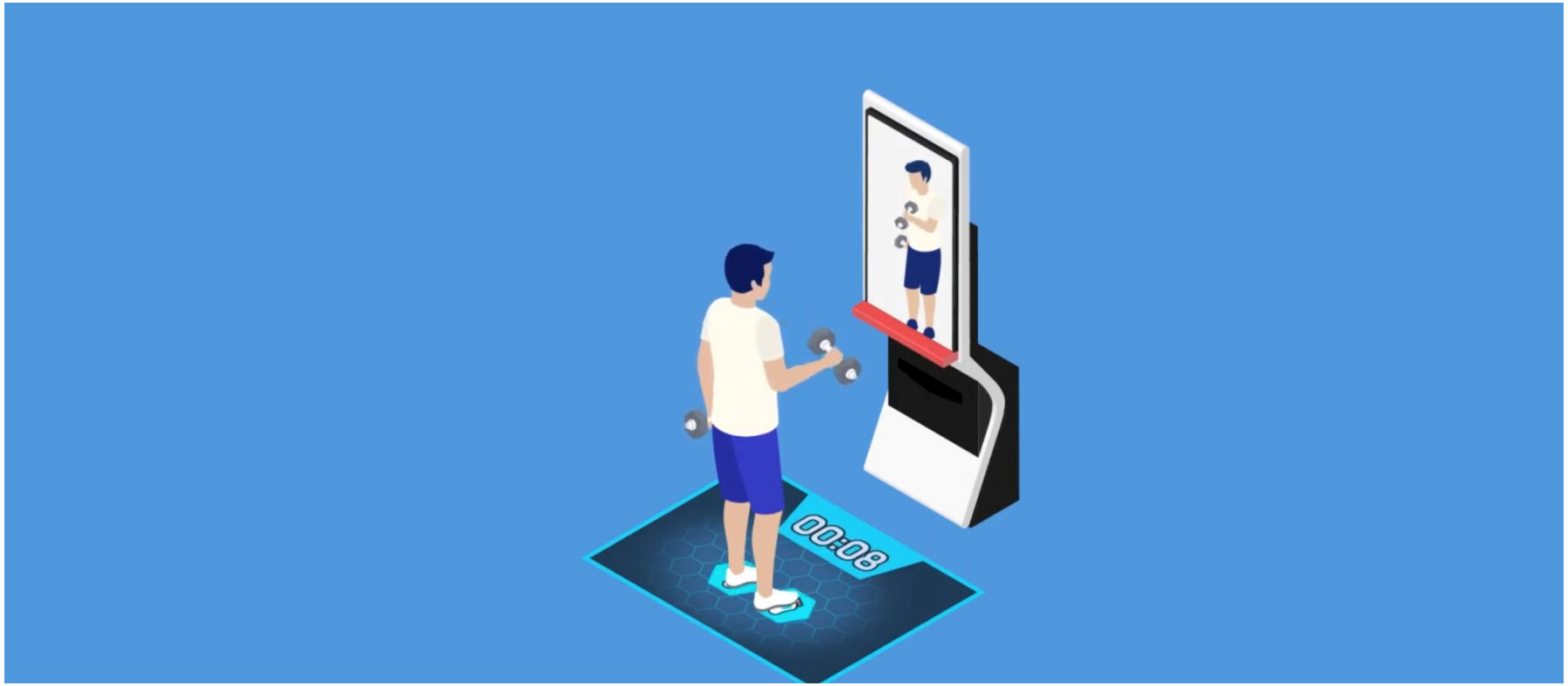


- Mixed reality is an emergent technology that blends virtual reality & augmented reality.

Bosché F et al. *J Comput in Civ Eng.* 2016; 30(2): 04015016

Mixed Reality Environment

Kinect-based mixed reality device



Interaction with Augmented Reality => **Mixed Reality**

Bosché F et al. *J Comput in Civ Eng.* 2016; 30(2): 04015016

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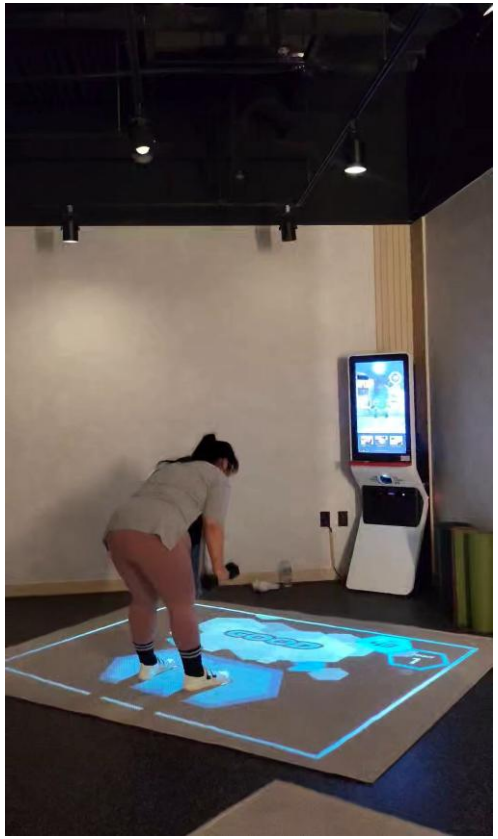
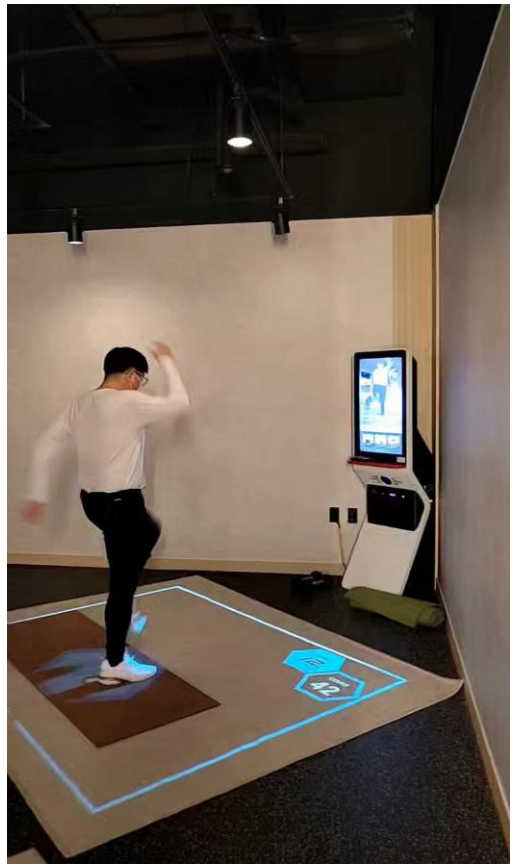
Kinect-based Mixed Reality (KMR) Device

- **Collaboration of Kinect and Mixed reality environment**





Kinect-based Mixed Reality (KMR) Device:

- Provide real time feedback by detecting 25 joints of the body and capture motions.
- All data is automatically saved in cloud server
- Exercise without supervisor

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Kinect-based Mixed Reality (KMR) Device

Bosché F et al. *J Comput in Civ Eng.* 2016

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Reliability and Validity of KMR

The Asian Journal of Kinesiology

Asian J Kinesiol 2022; 24(2): 2-11 · DOI: https://doi.org/10.15758/ajk.2022.24.2.2

Original Research

Reliability and Validity of the Kinect-Based Mixed Reality Device: Pilot Study

- **Excellent Reliability**
- (Cronbach alpha: 0.967, 0.969)
- **Strong Correlation**
- (r = .525 – .814, .718 – .958; very large)
- Regard to the Heartrate and Rated Perceived Exertion.

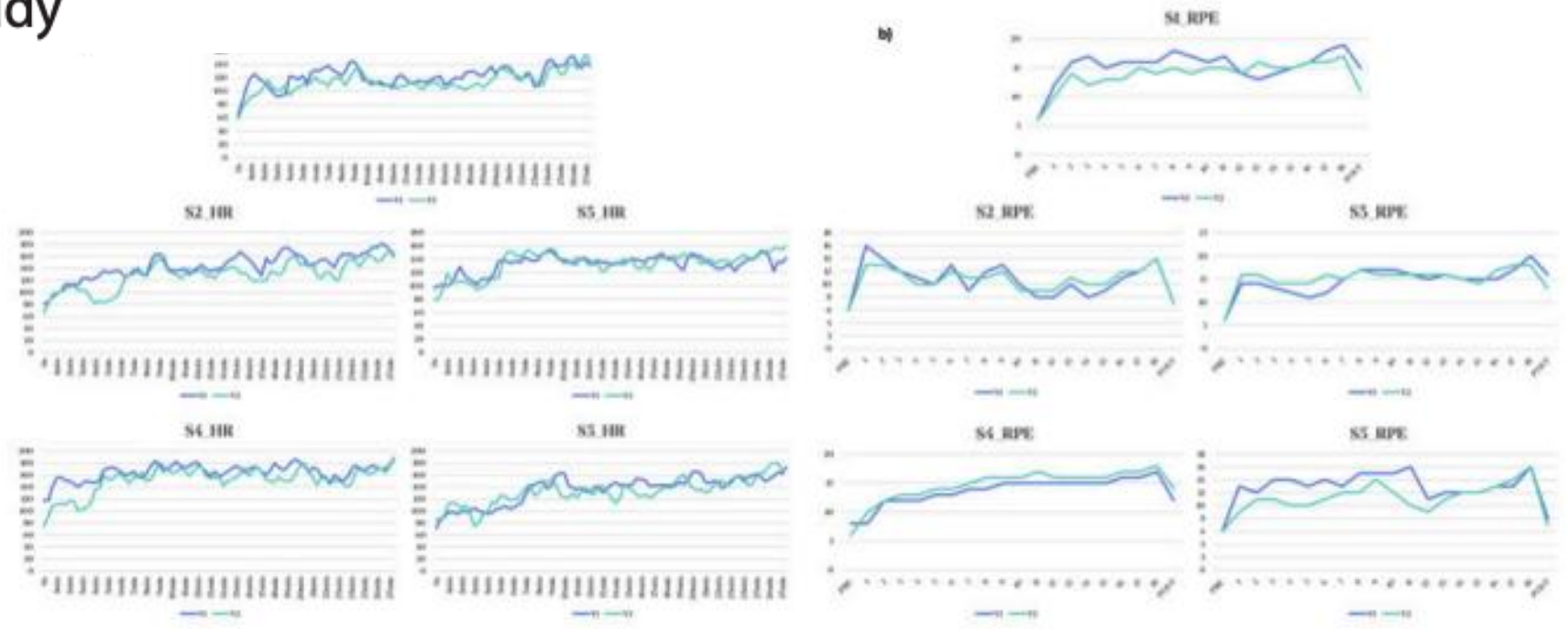

Figure 2. Flow chart of each subject's heart rate and rating of perceived exertion; a) flow chart of the heart rate. b) flow chart of the rating of perceived exertion. X-axis: mean data of visit 3; y-axis: mean data of visit 2. The correlation between visit 2 and visit 3 are shown as a flow chart.

Ahn, S. Y. et al (2022). *The Asian Journal of Kinesiology*, *24*(2), 2-11

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STUDY I

Effect of 2-week Kinect-Based Mixed Reality Exercise on Pre-diabetes with Continuous Glucose Monitoring System: A Pilot trial during COVID-19

Ahn, S. Y… **Song W.** et al. (2024). *Journal of Obesity & Metabolic Syndrome*.

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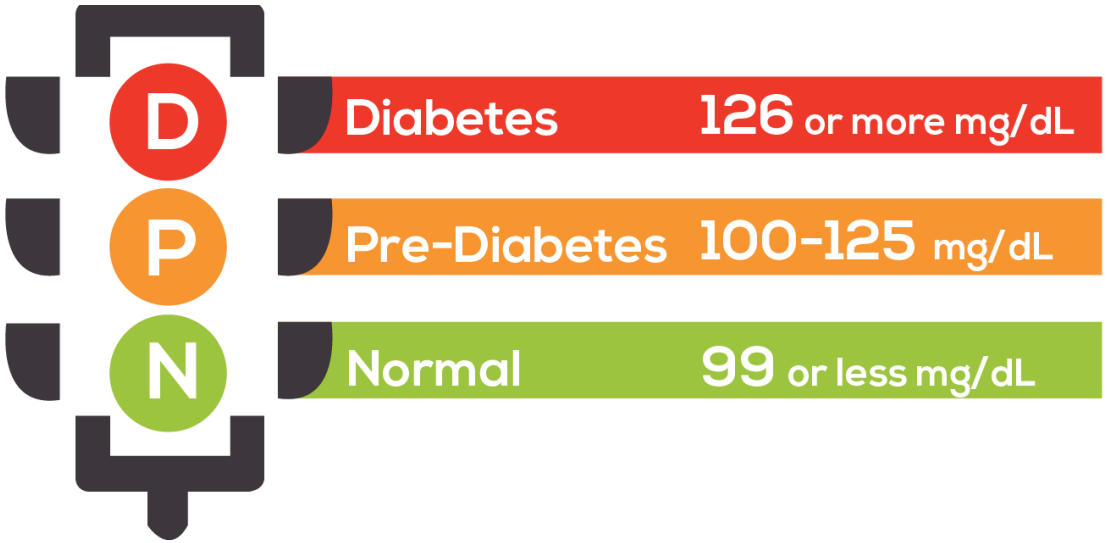
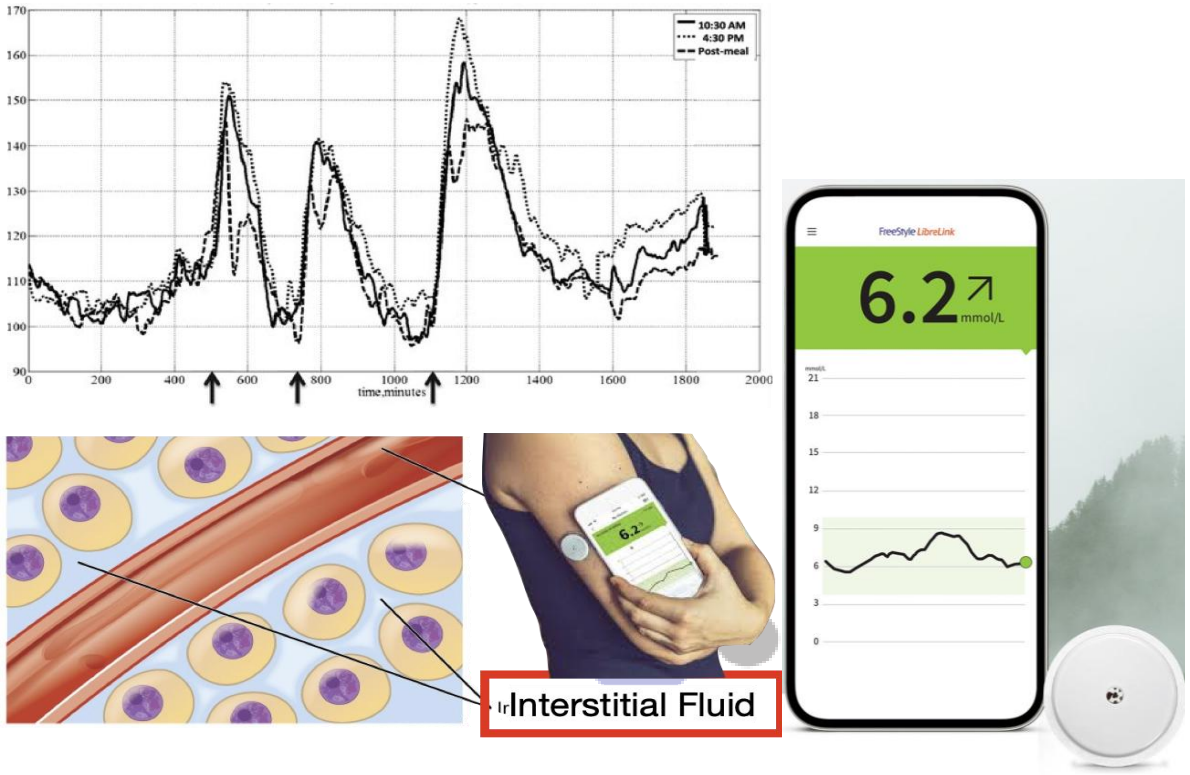
Research Background

Pre-diabetes and Continuous Glucose Monitoring System (CGMS)



Prediabetes is the last chance to reverse to be Diabetic



- Continuous Glucose Monitoring System is a recent device to help manage glucose level.
- Automatically measure Interstitial Fluid Glucose every 1min.
- Interstitial Fluid glucose level has a time gap with the blood glucose for 10 min.

Ahn, S. Y… **Song W.** et al. (2024). *Journal of Obesity & Metabolic Syndrome*.

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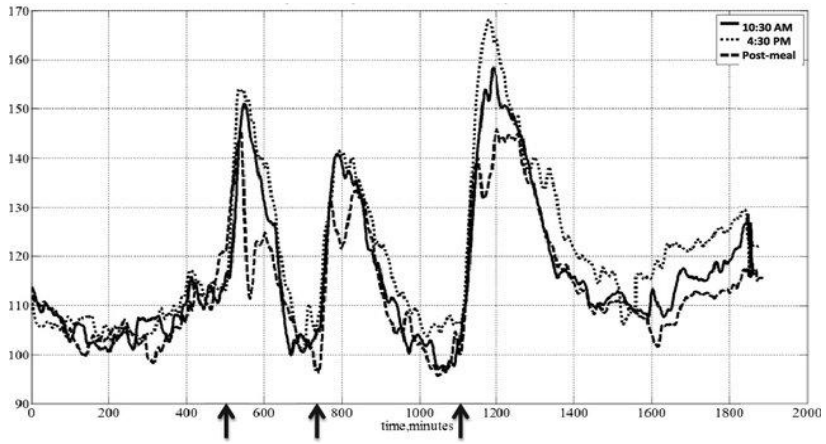
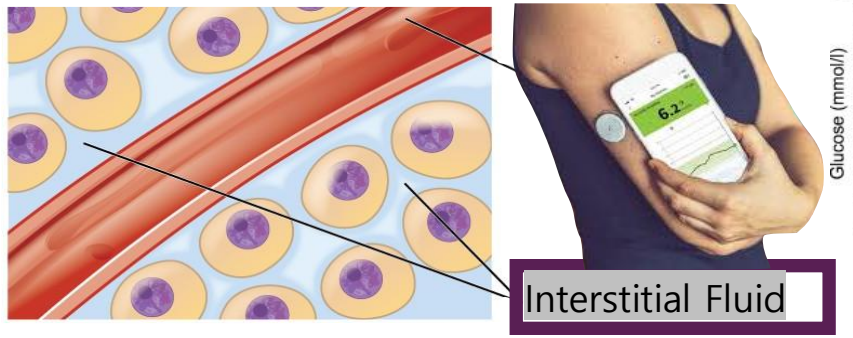
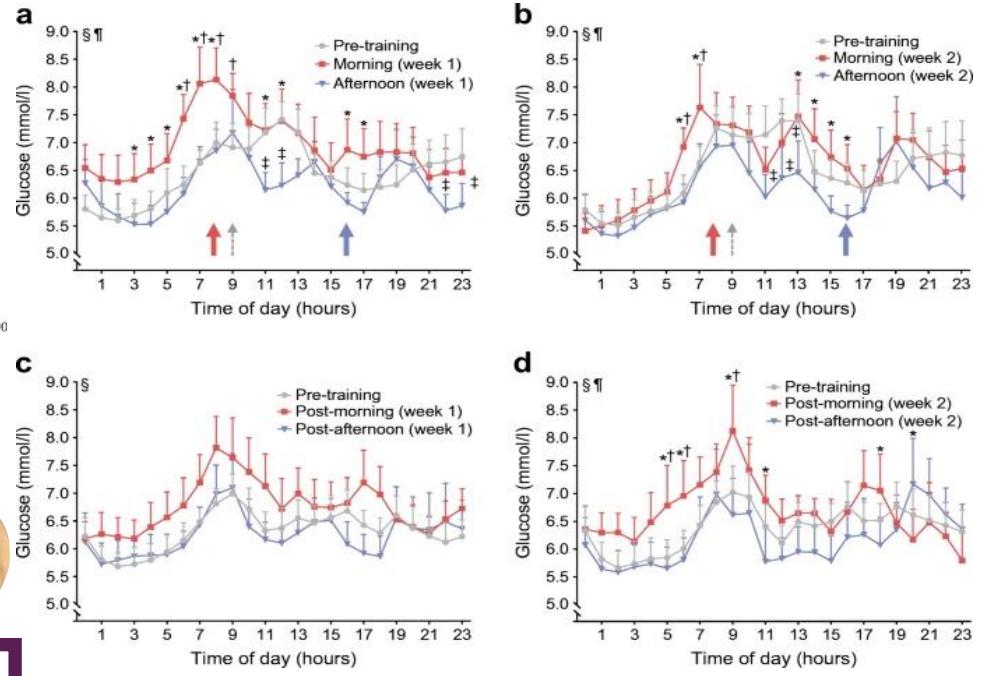
Research Background







Continuous glucose monitoring system (CGMS) is useful for diabetic patients
However, CGMS during exercise is an active area of research with mixed results.
And most studies examining the use of **CGMS during exercise** have focused on aerobic exercise and a single bout of activity

(Olivia Y., 2020).

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Research Objective

Aim of this Study:

To find out the impact on glucose level of **unsupervised Kinect-based mixed reality (KMR) exercise** program in individuals with pre-diabetes, using **continuous glucose monitoring system**

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Methods

Participants

- **Inclusion Criteria**

(1) BMI of 23kg/㎡ or more
(2) 29-59 years old
(3) Fasting glucose 100-125mg/dL
(4) 2-OGTT 140-199mg/dL

- **Exclusion Criteria**

(1) Acute hepatitis or a history of malignant tumors in the last 1 month
(2) Cerebral infarction or myocardial infarction in the last 6 months
(3) Peripheral vascular disease or dementia
(4) Participated regular exercise within 3 months
(5) Engaged with moderate to high-intensity exercise
(6) High blood pressure: >140/100mmHg.

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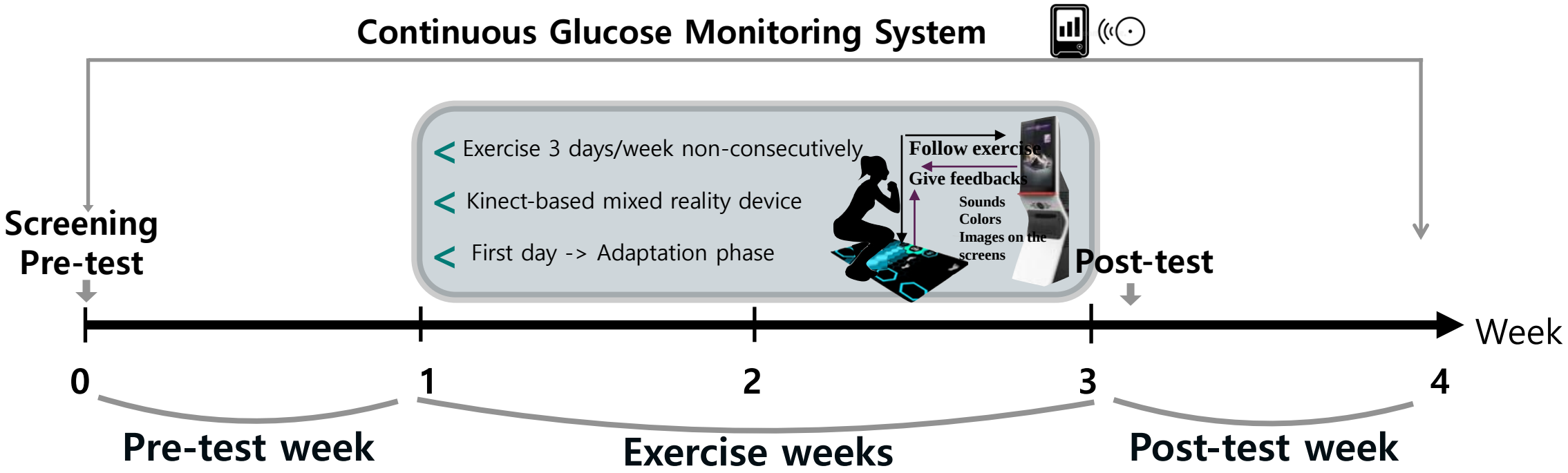
Methods

Participants



Study design for 4 weeks with CGMS including 2 week of Kinect-based mixed reality exercise.

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Methods

Exercise Program

Type(40min)	Contents	REP	Exercise Time(s)	Rest Time(s)
Warm up (5min)	Neck rotation		25	5
	Upper body forward bending		25	5
	Chest stretching		25	5
	Overhead triceps stretching		25	5
	Shoulder_rotation		25	5
	Arm rotation		25	5
	Hip rotation		25	5
	Knee rotation		25	5
	Standing hamstring and calf stretching		25	5
	Jump in place		25	5
Main exercise (8min × 3set)	Arm walking	7	45	15
	Bird dog_right	15	45	15
	Split squat_right	12	45	15
	High knee	65	45	15
	Two arm dumbbell row	15	45	15
	Bird dog_left	15	45	15
	Split squat_left	12	45	15
	Standing pike crunch	20	45	15
Rest (2min × 3set)				120
Cool down (5min)	Groin stretching		25	5
	Front body stretching_right		25	5
	Front body stretching_left		25	5
	Shoulder static stretching		25	5
	Hamstring stretching_right		25	5
	Hamstring stretching_left		25	5
	Body trunk stretching		25	5
	Lunge stretching_right		25	5
	Lunge stretching_left		25	5
	Abdomen stretching		25	5

30 min of circuit-based exercise

8 min of main exercise/set * 3 sets

Big major muscle groups of the whole body

(e.g., Quadriceps, Deltoids, etc.)

Warm-up (Dynamic stretching)

Cool-down (Static stretching)

Main exercise (45 s of exercise & 15 s of a rest)

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Methods

Measurements

Lab basis

InBody Co., Ltd, Seoul, Korea

Blood pressure

InBody 720, Seoul, Korea

ISECA201, Hamburg, Germany

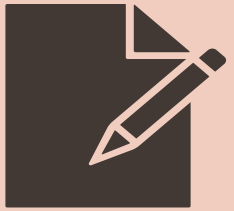
Body composition

GPAQ

Physical activity level

Roche Diabetes Care GmbH, Germany

Blood glucose



Intention

Exercise Intention

Weekly basis

Galaxy fit2, Samsung, Korea

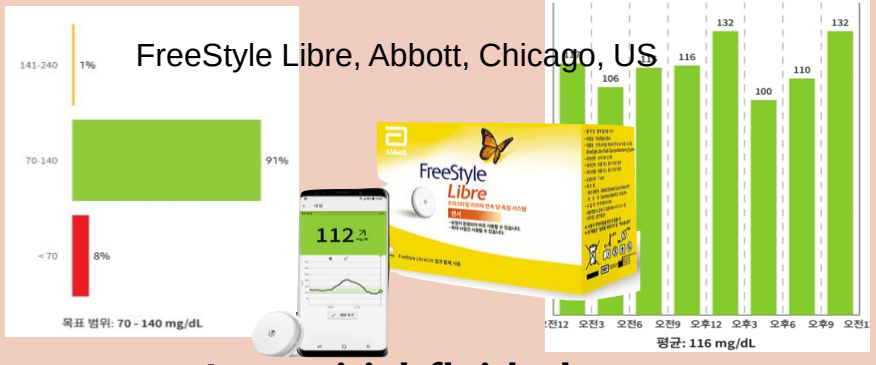
Physical activity

3 days recall / CanPro5

Nutrient intake

Maintenance of lifestyle

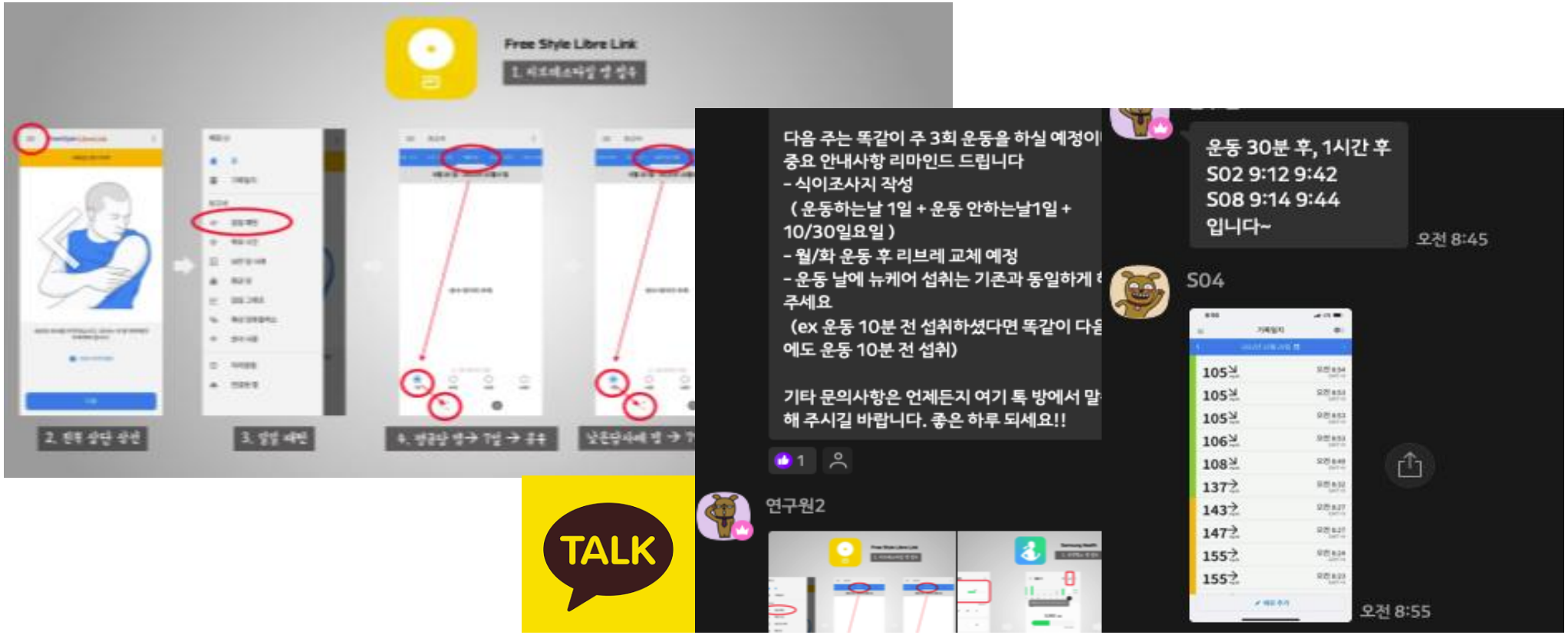
FreeStyle Libre, Abbott, Chicago, US



Interstitial fluid glucose

Methods

Measurements



Anonymous chat was created to deliver notices and collect necessary data (e.g., tagging the smartphone to the device 3 times a day.)
It was anonymous to avoid “social facilitation effect”.

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Methods

Statistical Analysis

SPSS Version 25.0

Data as mean ± standard deviation (SD)

Descriptive statistical analyses for demographic variables

Shapiro-Wilk test for normality at the baseline

Paired sample t-tests for continuous variables

$P < .05$ (Cohen's d).

- Small effect size: d = 0.2
- Medium effect size: d = 0.5
- Large effect size: d = 0.8

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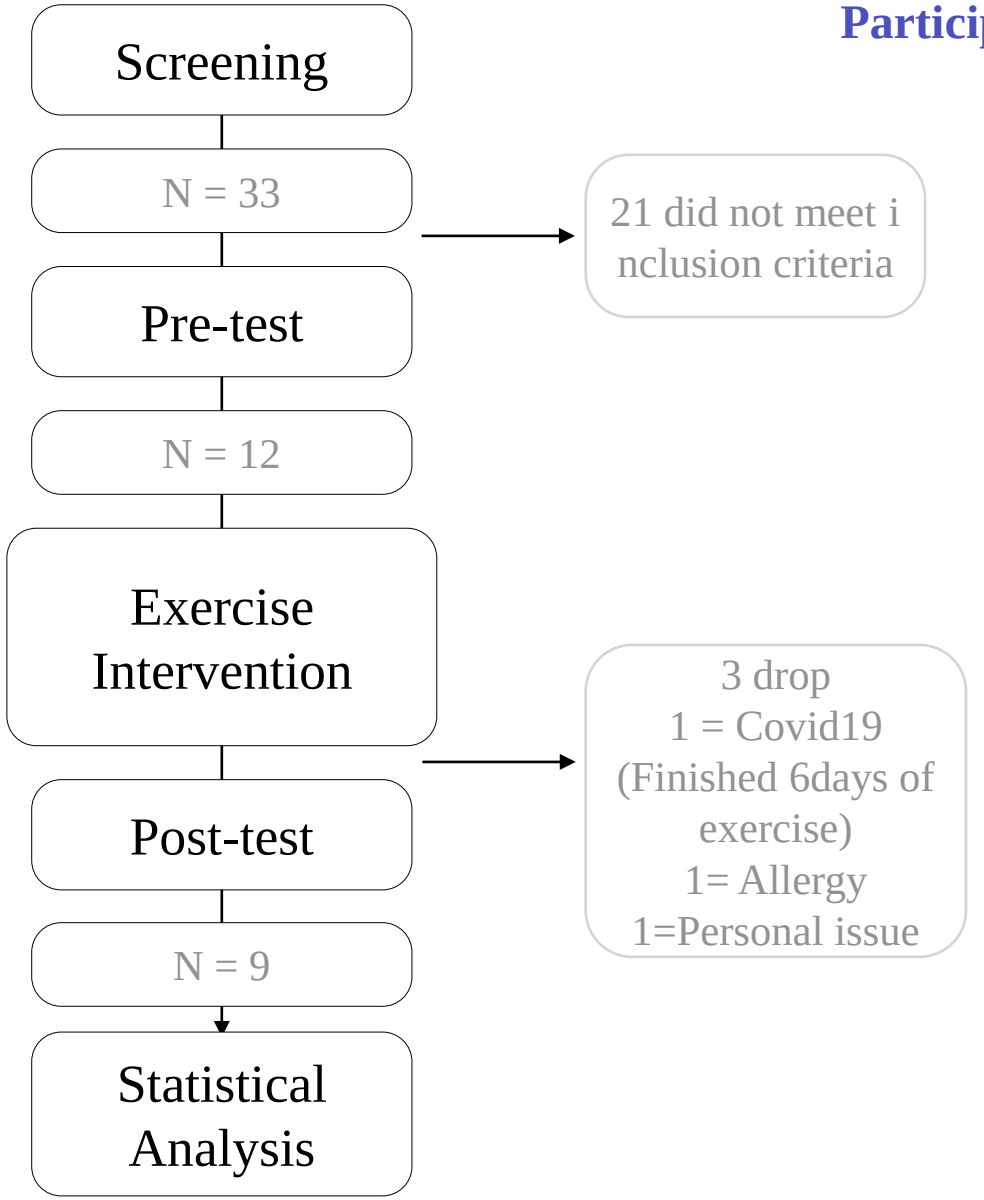
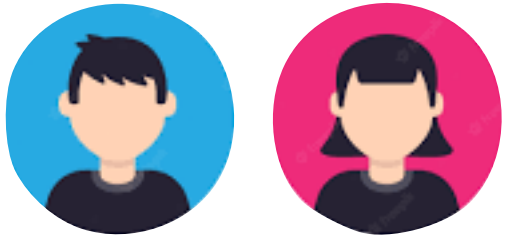
Results

Participants



	Mean±SD
Age	42.89 ± 10.54
Height	167.30 ± 6.48
Weight	75.60 ± 4.96
Fasting_Glucose	108.00 ± 7.19
Oral_2hr_Glucose	162.56 ± 18.12



N=5 N=4

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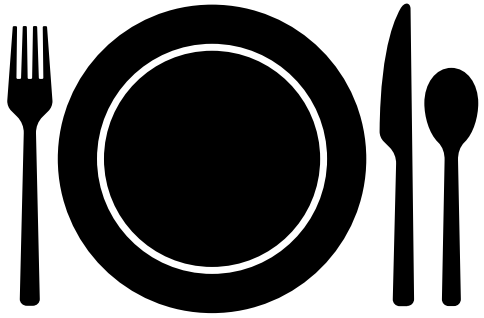
Results

Maintenance of lifestyle
(Weekly physical activity level and nutrient intake)



Total energy intake

3-day recall at W1 was 2362 ± 730.247 kcal, at W2-3 was 2507.8462 ± 840.425 kcal, and W4 was 2429.9513 ± 800.730 kcal.

Physical activity level

Average number of steps per week at W1 was 9023.67 ± 4482.02 steps, W2-3 was 166 32.00 ± 20676.97 steps, and “W4 was 9076. 00 ± 5276.80 steps.

Neither total energy **nor** physical activity showed significant difference between weeks.

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Results

Visit measurements (pre and post-tests)

Table 1. Visit measurements of body composition, blood pressure, and blood glucose level of pre and post-tests

	Pre-test	Post-test	*P-value*[a]
Weight (kg)	75.53±4.68	75.71±4.61	.656 (.038)
Fasting glucose (mg/dL)	108.00±7.20	109.67±11.50	.695 (.174)
Oral glucose tolerance test (mg/dL)	162.67±18.30	142.56±37.93	**.044*** **(.675)**
Waist circumference (cm)	90.17±3.86	89.50±4.60	.477 (.158)
Skeletal muscle mass (kg)	28.09±3.43	28.49±3.77	.254 (.111)
Body fat (%)	29.54±9.34	28.81±9.30	.166 (.078)
Fat free mass (kg)	50.40±5.47	51.13±6.13	.228 (.126)
Body mass index (kg/m²)	27.16±2.92	24.03±8.23	.341 (.507)
Systolic blood pressure (mmHg)	131.00±9.35	126.11±12.10	.176 (.452)
Diastolic blood pressure (mmHg)	82.89±8.45	78.11±12.37	**.046*** **(.451)**

Values are presented as mean±standard deviation. [a]*P*-value are presented as *P*-value (cohen's *d*). *$P < .05$

2-OGTT level and DBP were significantly decreased after the intervention.
Intention to continue participating in the same exercise program after the intervention showed high score in **all 3 questions.** Scored 6.67 ± .50 (7: very positive).

Ahn, S. Y… **Song W.** et al. (2024). *Journal of Obesity & Metabolic Syndrome*.

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Results

Exercise participation

Exercise participation rate of the total 5 day s was **114.11 ± 28.52%**

Exercise participation rate = (Reps done by participants / Suggested minimum reps)* 100%

Suggested minimum reps are for minimum standard for them to participate properly

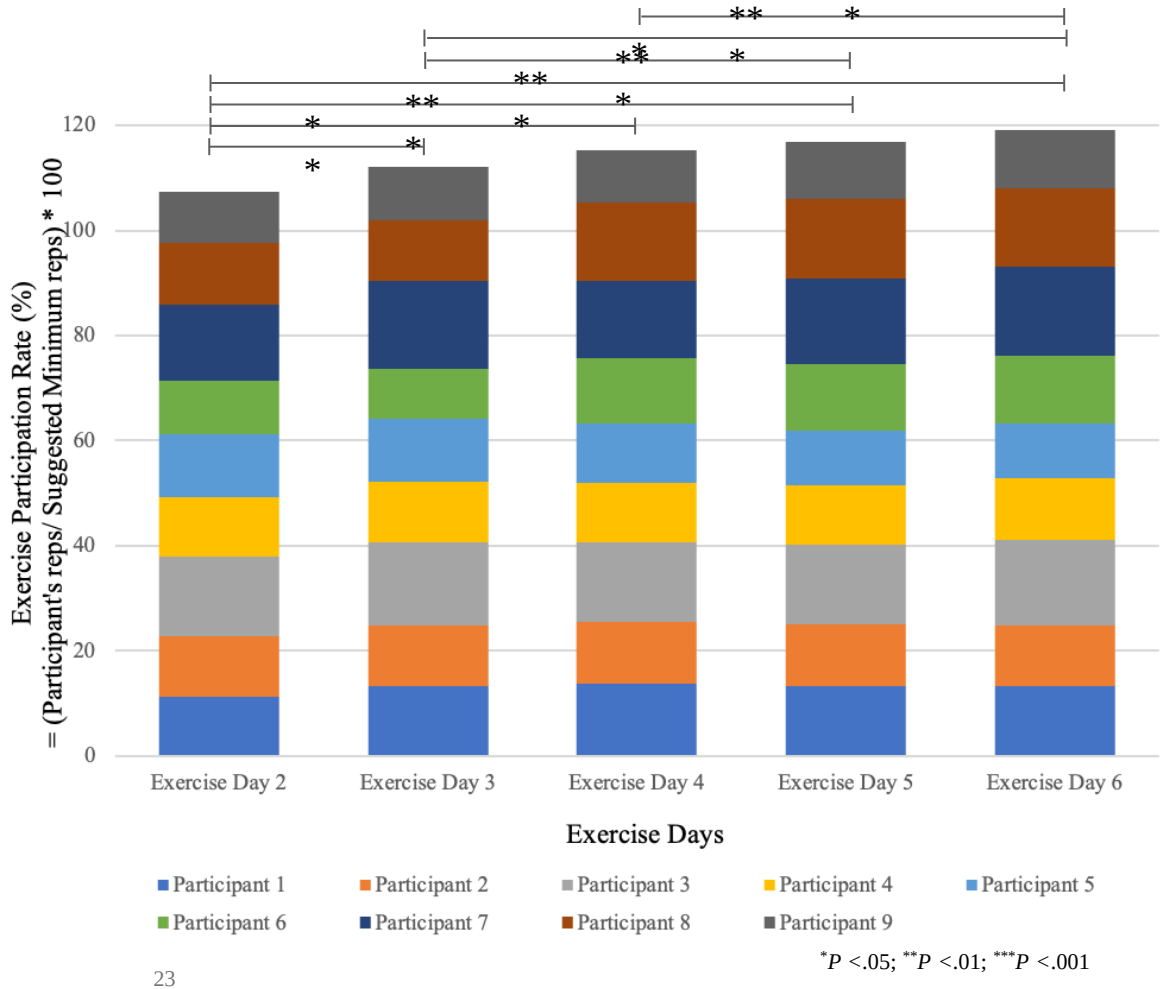

Fig 2. Exercise participation rate over 5 exercise days with a Kinect-based mixed reality device.

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Results

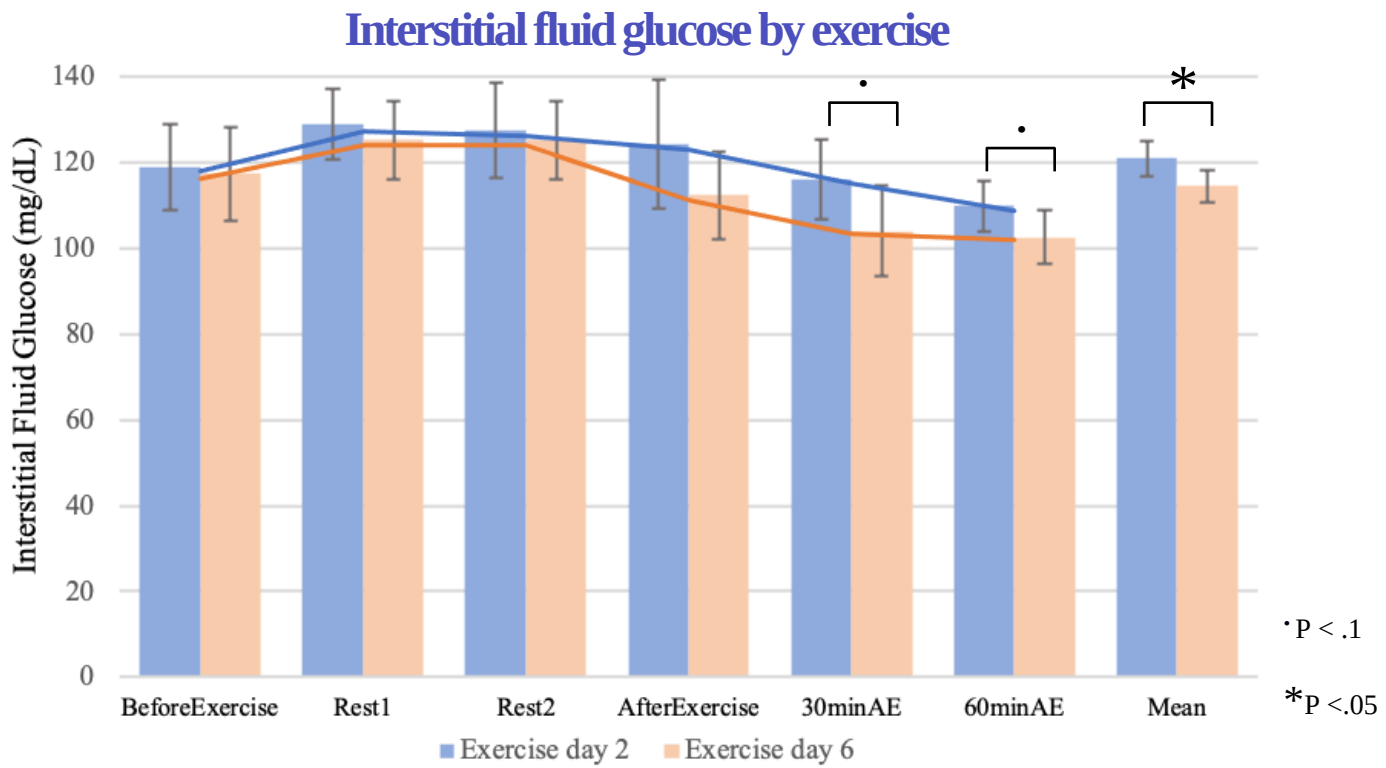

Fig 3. Interstitial fluid glucose levels during Kinect-based mixed reality exercise: Day 2 vs. Day 6.

Exercise day 6 showed a tendency to decrease in 30 min (P<.076) and 60 min after exercise (P<.075) and **mean glucose level of whole period** from before exercise to 60 min after exercise showed a significant decrease (P<.016) compared to Exercise day 2

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Results

Weekly measurements

Table 2. Weekly continuous glucose monitoring data for 4 weeks

	Pre test week (Week 1)	Exercise week 1 (Week 2)	*P-value*[a]	Exercise week 2 (Week 3)	*P-value*[b]	Post test week (Week 4)	*P-value*[c]
Hypoglycemia (%)	2.11±5.26	.11±.33	.290 (.537)	2.00±2.55	.961 (.027)	1.22±1.72	.652 (.023)
Hyperglycemia (%)	9.22±10.95	8.78±10.96	.695 (.040)	5.89±8.84	**.040* (.335)**	11.44±12.49	.267 (.189)
Mean glucose (mg/dl)	105.44±16.31	109.11±12.19	.122 (.255)	102.89±12.74	.302 (.174)	108.22±13.82	.463 (.184)
AM 12_3 (mg/dl)	110.22±41.89	103.56±16.00	.505 (.210)	97.67±17.59	.182 (.390)	102.56±22.22	.311 (.228)
AM 3_6 (mg/dl)	92.33±14.07	94.89±7.25	.482 (.228)	90.33±11.60	.508 (.115)	91.22±6.61	.839 (.101)
AM 6_9 (mg/dl)	93.78±12.79	104.78±15.39	**.008** (.777)**	98.78±14.95	.172 (.359)	99.11±8.89	.264 (.484)
AM 9_12 (mg/dl)	105.56±16.86	110.22±12.06	.145 (.318)	106.11±13.57	.891 (.036)	109.22±17.30	.425 (.214)
PM 12_3 (mg/dl)	121.67±24.41	121.56±21.92	.968 (.005)	114.78±27.64	.075 (.264)	122.33±18.77	.908 (.030)
PM 3_6 (mg/dl)	103.44±13.78	110.67±14.84	**.006** (.505)**	106.22±13.56	.501 (.203)	109.33±13.46	.184 (.432)
PM 6_9 (mg/dl)	107.56±11.27	113.33±10.12	.104 (.539)	102.89±7.94	.152 (.479)	120.22±21.14	**.036* (.747)**
PM 9_12 (mg/dl)	116.22±21.56	116.78±24.59	.912 (.024)	113.22±21.52	.522 (.139)	114.56±22.96	.660 (.075)

Weekly average hyperglycemia rate in Week 3 was significantly decreased, Weekly average glucose at '6-9 am' and '3-6 pm' was significantly increased in Week 2, and '6-9 pm' was significantly increased in Week 4 compared to the Week 1.

Ahn, S. Y… **Song W.** et al. (2024). *Journal of Obesity & Metabolic Syndrome*.

Results

Weekly measurements

Table 3. Postprandial interstitial fluid glucose level by continuous glucose monitoring system for 4 weeks

	Pre test week (W1)	Exercise week 1-2 (W2-3)	*P-value*[a]	Post test week (W4)	*P-value*[b]
Before lunch	100.00±18.85	106.83±14.19	.149 (.409)	102.19±20.64	.632 (.111)
After lunch	124.48±31.44	123.20±22.48	.884 (.049)	121.85±24.78	.755 (.093)
30 min After lunch	148.82±38.44	136.44±27.07	.176 (.372)	138.41±27.01	.354 (.313)
60min After lunch	143.07±32.67	142.78±29.25	.977 (.009)	142.96±27.98	.991 (.004)
90min After lunch	129.19±23.91	119.68±17.08	**.035* (.458)**	124.33±19.80	.542 (.221)
120min After lunch	115.00±22.41	115.07±16.40	.990 (.004)	110.85±19.32	.527 (.198)

[a]*P*-value between Pre exercise week (W1) and Exercise week 1-2 (W2-3); [b]*P*-value between Pre exercise week (W1) and Post exercise wk (W4); * *P* <.05; Values are presented as mean±standard deviation. *P*-value are presented as *P*-value (cohen's *d*).

There was a significant **decrease** in **postprandial glucose at 90 minutes** after lunch at W2-3 compared to W1.

Ahn, S. Y… **Song W.** et al. (2024). *Journal of Obesity & Metabolic Syndrome*.

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Discussion

- To our knowledge, This study is the first to track the changes in interstitial fluid glucose levels during unsupervised exercise in individuals with pre-diabetes.

- We tracked ISF glucose for about **672** hours per participant to evaluate the changes in glucose level. The study found that a 2-week unsupervised exercise program improved **2-hour oral glucose tolerance test (2-OGTT) levels and diastolic blood pressure**, and may change postprandial glucose levels.

- Compliance among participants was **high**, and they expressed a desire to participate in another month-long program (Intention survey).

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Conclusion

While some of the weekly average glucose levels' daily time significantly increased, the main outcome of **2-OGTT, DBP, hyperglycemia rate, and postprandial glucose** decreased without adverse events.

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STUDY II

“Effects of 8 Weeks of Kinect-based Mixed Reality Exercise and Deep-sea Water Consumption on Metabolic Syndrome : A Randomized Controlled Trial”

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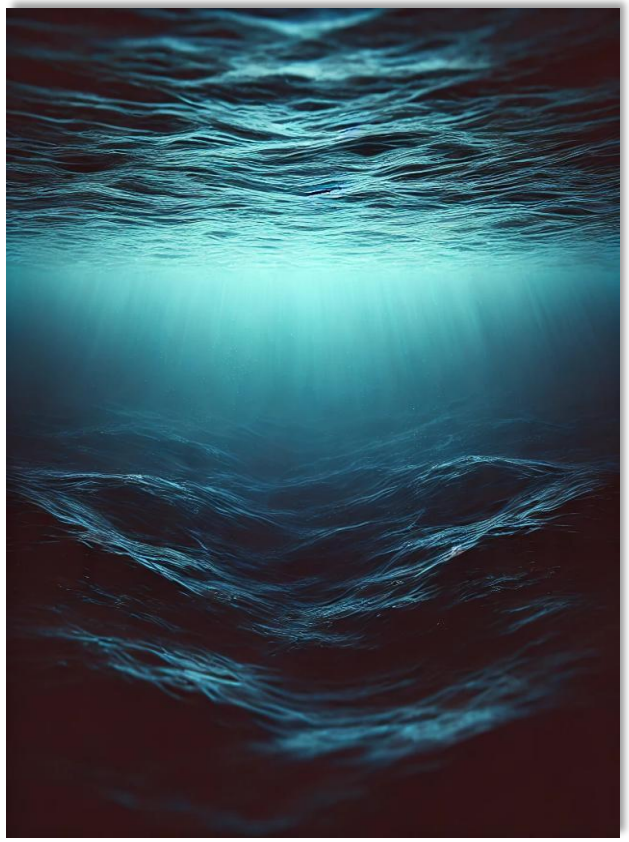
Research Background

Deep Sea Water (DSW)



[Total elements of deep-sea water]

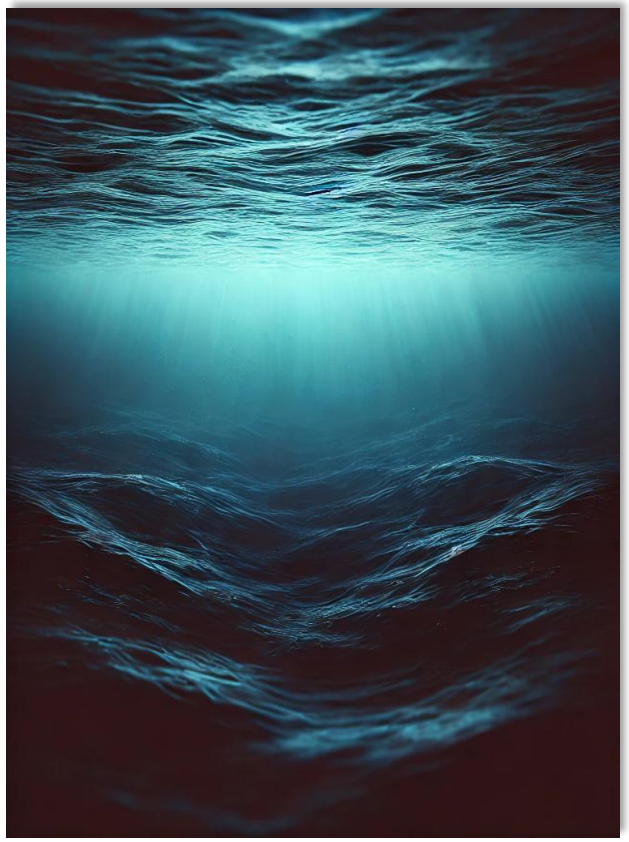
Cl, Na, Mg, S, Ca, K, Br, C, N, Sr, B, O, Si, F, Ar, Li, Rb, P, I, Ba, Mo, U, V, As, Ni, Zn, Kr, Cs, Cr, Sb, Ne, Se, Cu, Cd, Xe, Fe, Al, Y, Zr, Tl, W, Re, He, Ti, La, Ge, Nb, Hf, Nd, Ta, Ag, Co, Ga, Er, Yb, Dy, Gd, Pr, Ce, Se, Sm, Sn, Ho, Lu, Be, Tm, Eu, Hg, Rh, Te, Pd, Pt, Bi, Au, Th, In, Ru, Os, Ir

(Nani,M.,et al, 2016)

- **Natural resource** exists at a **depth of more than 200m** *(Ham, J. Y., et al, 2020)*
- **High contents of unique minerals**: Mg, Ca, K, Zn, V *(Ha, B. G., et al, 2013)*
- Depth of sea water ↑, amount of mineral material ↑

Research Background

Deep Sea Water (DSW)



High contents of unique minerals: Mg, Ca, K, Zn, V *(Ha, B. G., et al, 2013)*

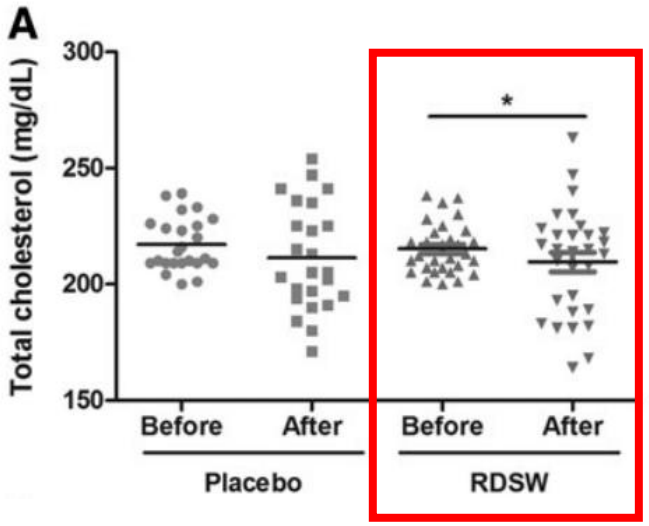
- Important **metabolic electrolyte**
- **Cofactor** in more than **300 enzyme systems** that **regulate** a variety of body biochemical reactions, in energy generation, enzyme activation, cardiovascular system, membrane function, and nutritional metabolism

➔ **Mineral waters** beneficial effects

: **blood pressure**, **total-triglycerides**, **HDL-cholesterol** and **glucose**

Research Background

Deep Sea Water (DSW)



(Kim et al., 2020)

Table 6. Changes in blood lipid profile before and after ingestion.

	BDSW group (n = 37)				Placebo group (n = 37)				p-Value [2]
	Baseline	8 Weeks	Change Value	p-Value [1]	Baseline	8 Weeks	Change Value	p-Value [1]	
TC (mg/dL)	204.30 ± 33.94	198.62 ± 33.21	−5.68 ± 28.70	0.237	194.62 ± 34.08	205.03 ± 33.71	10.41 ± 23.02	0.009 **	0.006 **
TG (mg/dL)	138.81 ± 64.57	141.68 ± 81.61	2.86 ± 78.97	0.827	161.46 ± 100.70	140.14 ± 78.78	−21.32 ± 78.09	0.105	0.184
HDL-C (mg/dL)	48.05 ± 8.93	49.14 ± 9.48	1.08 ± 7.34	0.376	47.22 ± 9.23	49.95 ± 9.36	2.73 ± 5.35	0.004 **	0.289
LDL-C (mg/dL)	128.41 ± 29.80	121.19 ± 32.86	−7.22 ± 28.44	0.131	116.22 ± 33.00	127.22 ± 29.21	11.00 ± 23.68	0.008 **	0.003 **

Values are presented as mean ± SD. ** $p < 0.01$. Change value = value at 8 weeks − baseline value. [1] Analyzed by paired t-test compared within the group. [2] Analyzed by an independent t-test change values of the comparison between groups (analyzed by a linear mixed effect model for repeated measures data).

Table 5. Changes in blood glucose-related indicators before and after ingestion.

	BDSW Group (n = 37)				Placebo Group (n = 37)				p-Value [2]
	Baseline	8 Weeks	Change Value	p-Value [1]	Baseline	8 Weeks	Change Value	p-Value [1]	
FPI (μU/mL)	8.66 ± 4.87	7.59 ± 3.87	−1.07 ± 3.97	0.110	7.95 ± 3.88	8.62 ± 4.14	0.67 ± 2.76	0.151	0.042 *
HOMA-IR	2.13 ± 1.19	1.87 ± 0.92	−0.27 ± 1.01	0.113	1.96 ± 1.03	2.13 ± 1.03	0.17 ± 0.70	0.157	0.049 *
C-peptide (ng/mL)	1.94 ± 0.70	1.87 ± 0.49	−0.07 ± 0.53	0.452	1.91 ± 0.55	1.96 ± 0.57	0.05 ± 0.30	0.311	0.263
HbA1c (%)	5.82 ± 0.30	5.83 ± 0.32	0.01 ± 0.17	0.846	5.80 ± 0.32	5.84 ± 0.31	0.04 ± 0.15	0.088	0.249

Values are presented as mean ± SD. * p <0.05. Change value = value at 8 weeks − baseline value. [1] Analyzed by paired t-test compared within the group. [2] Analyzed by independent t-test change values of the comparison between groups (analyzed by a linear mixed effect model for repeated measures data).

(Ham et al., 2020)

Research Background

Kinect-based Mixed Reality Exercise

STUDY I

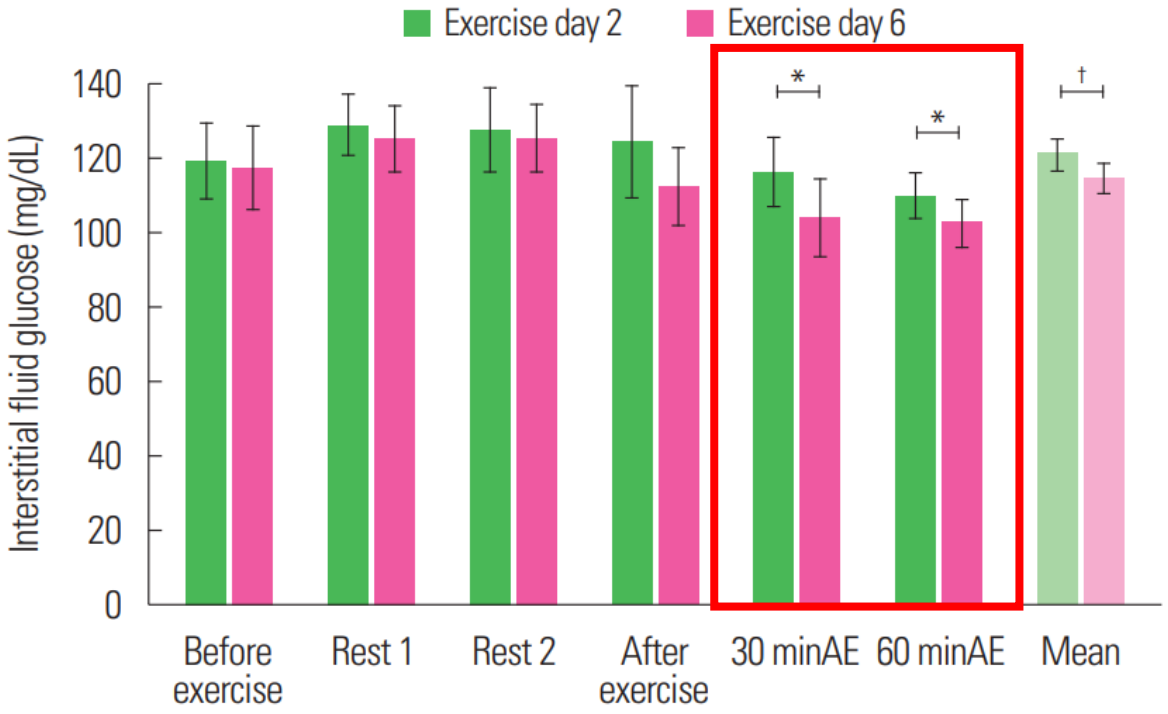


Figure3. Interstitial fluid glucose concentrations during Kinect-based mixed-reality exercise: day 2 vs. day 6.

Ahn, S. Y… **Song W.** et al. (2024). *Journal of Obesity & Metabolic Syndrome*.

Research Objective

Thus, this study investigated the effects of Kinect-based Mixed Reality exercise and consumption of deep-sea water on metabolic syndrome.

Methods

Subjects and Recruitment

Inclusion criteria

25 and 65 years old who met diagnostic criteria for metabolic syndrome

* Diagnosis criteria

: National Cholesterol Education Program Adult Treatment Panel III (modified NCEP ATP III)

Risk factors	Men	Women
Waist circumference (cm)	≥90	≥85
HDL cholesterol (mg/dL)	<40	<50
Fasting glucose (mg/dL)	≥100 or medication	
Triglyceride (mg/dL)	≥150 or medication	
Blood pressure (mmHg)	≥130 / ≥85 or medication	

→ If more than 3 of these criteria are met, MetS is diagnosed

Methods

Week		
0	**Pre-test Screening**	Waist circumferences, Blood pressure, Global Physical Activity Questionnaire (GPAQ), Beck Depression Inventory (BDI), Quality of Life (QoL), Body composition, Blood sampling, Diet records.
1~8	**8 weeks Intervention**	* Randomization → **Con** : control group → **DSW** : consumption deep-sea water group → **KMR** : kinect-based mixed reality exercise group → **DSW+KMR** : consumption deep-sea water + Kinect-based mixed reality exercise group
9	**Post-test**	Waist circumferences, Blood pressure, GPAQ, BDI, QOL, Body composition, Blood sampling, Diet records.

Methods

Lab

BPBIO750

SECA201

BSM370

Inbody770

Blood pressure

Body composition

GPAQ, BDI, QOL

Questionnaires

Can pro 6.0

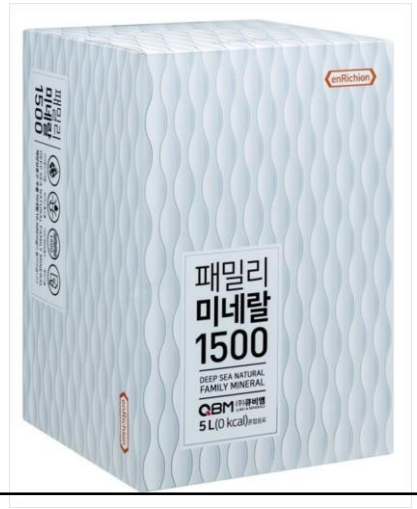
Diet Analysis

Weekly

Amazefit gts4 mini

Maintenance of lifestyle

Methods



- Drink a 440mL/d of desalinated deep-sea water *(Hou et al., 2013)*
- Collected at Ulleungdo Island
- Hardness & Depth : 1500 *(Ham & Shon, 2020)*
- Contains 72 minerals
- Log daily consumption intake

Component		Mixing Ratio (%)	Mineral	(mg/L)
Main component	Mineral-enriched desalted deep-sea water	99.95	Magnesium(Mg)	320
			Potassium(K)	128
			Sodium(Na)	144
Minor component	Magnesium Chloride	0.05	Magnesium(Mg)	50
	Total hardness			1517

Methods

Exercise Program

- **40 minutes of** circuit training
  - Warm-up (5mins)
  - Main exercise (30mins)
  - Cool down (5mins)
- 3 times per week for 8 weeks *(Arazi, H., 2020)*
- **Dumbbell : Male, 5kg / Female, 3kg**

Type(40min)	Contents	REP	Exercise Time(s)	Rest Time(s)
Warm up (5mins)	Neck rotation		25	5
	Upper body forward bending		25	5
	Chest stretching		25	5
	Overhead triceps stretching		25	5
	Shoulder_rotation		25	5
	Arm rotation		25	5
	Hip rotation		25	5
	Knee rotation		25	5
	Standing hamstring and calf stretching		25	5
	Jump in place		25	5
Main exercise * 3set (8mins/set)	Arm walking	7	45	15
	Bird dog_right	15	45	15
	Split squat_right	12	45	15
	High knee	65	45	15
	Two arm dumbbell row	15	45	15
	Bird dog_left	15	45	15
	Split squat_left	12	45	15
	Standing pike crunch	20	45	15
Rest (2mins/set)				
Cool down (5mins)	Groin stretching		25	5
	Front body stretching_right		25	5
	Front body stretching_left		25	5
	Shoulder static stretching		25	5
	Hamstring stretching_right		25	5
	Hamstring stretching_left		25	5
	Body trunk stretching		25	5
	Lunge stretching_right		25	5
	Lunge stretching_left		25	5
	Abdomen stretching		25	5

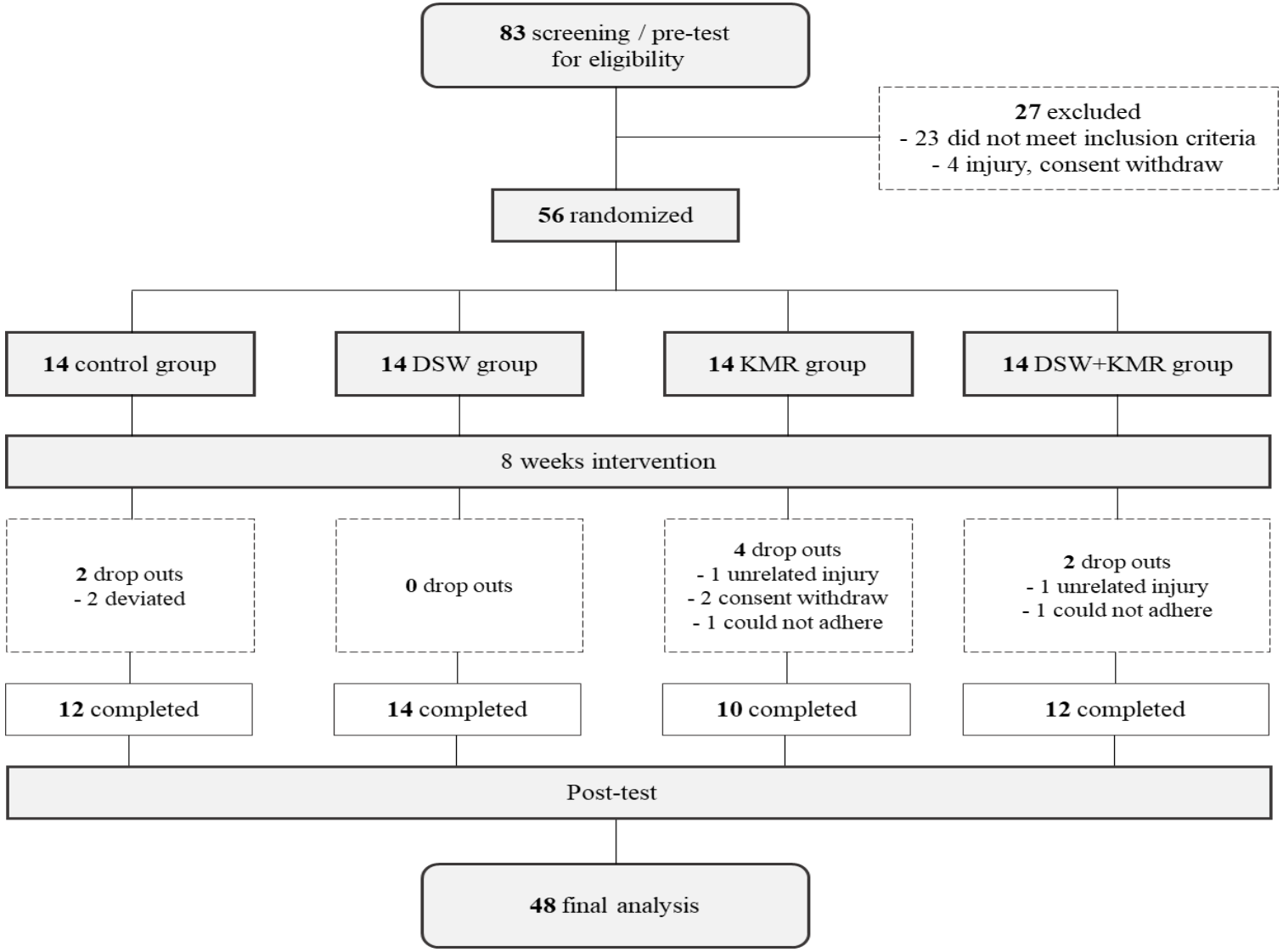
(Ahn et al., 2024)

Methods

Statistical Analysis

- ✓ Statistical analysis was performed by using GraphPad Prism 10.1.0.
- ✓ Values of $P<0.05$ were considered statistically significant.
- ✓ All data was presented with the mean ± standard deviation (SD).
- ✓ One-way ANOVA for baseline group comparison
- ✓ Two-way ANOVA for time * group comparison
- ✓ Bonferroni for post hoc test

Results


83 screening / pre-test for eligibility
27 excluded
- 23 did not meet inclusion criteria
- 4 injury, consent withdraw
56 randomized
14 control group
14 DSW group
14 KMR group
14 DSW+KMR group
8 weeks intervention
2 drop outs
- 2 deviated
0 drop outs
4 drop outs
- 1 unrelated injury
- 2 consent withdraw
- 1 could not adhere
2 drop outs
- 1 unrelated injury
- 1 could not adhere
12 completed
14 completed
10 completed
12 completed
Post-test
48 final analysis

Results

Compliance

Kinect-based mixed reality exercise

98.4%

Deep-sea water consumption

99.2%

Results

Maintenance of lifestyle
(Weekly physical activity level and nutrient intake)

Total energy intake

Physical activity level

Characteristics	Con (n=12)		DSW (n=14)		KMR (n=10)		DSW+KMR (n=12)		*F*	*P*
	Pre	Post	Pre	Post	Pre	Post	Pre	Post		
Total calorie intake (Kcal/day)	1875.00 ± 816.41	1906.67 ± 574.58	1764.93 ± 570.45	1611.50 ± 451.91	1723.00 ± 383.93	1692.00 ± 253.91	1860.42 ± 625.39	1853.08 ± 735.06	0.288	0.834
GPAQ score (MET/day)	558.18 ± 498.35	1275.00 ± 1569.95	1300.00 ± 1303.60	1360.00 ± 1616.76	1435.56 ± 2086.38	1684.00 ± 1914.64	896.67 ± 1000.58	1586.67 ± 1094.63	0.844	0.477

Mean±Standard Deviation. Values indicated are significantly different from baseline (pre) values. *p<.05. Abbreviations: Con = control group; DSW = consumption deep-sea water group; KMR = kinect-based mixed reality exercise group; DSW+KMR = consumption deep-sea water and Kinect-based mixed reality exercise group.

Excluding the exercise group,
there were **no significant changes in dietary caloric intake and physical activity levels.**

Results

Baseline Characteristics

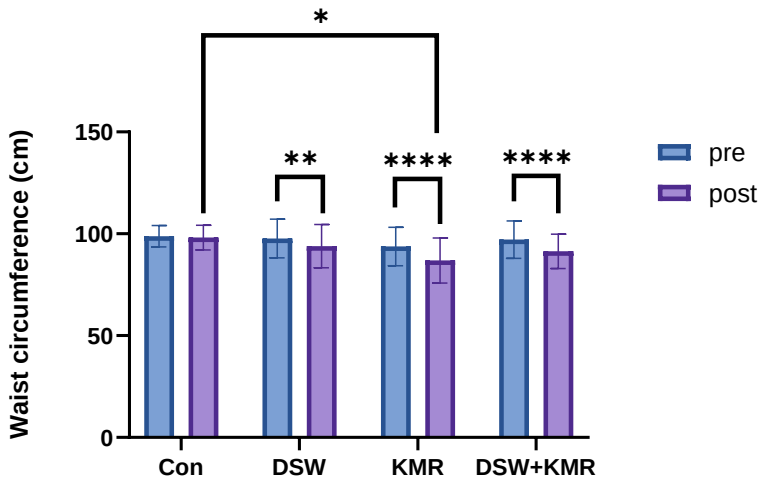
Characteristics	All (n=48)	Con (n=12)	DSW (n=14)	KMR (n=10)	DSW+KMR (n=12)	*F*	*P*
Age (yr), mean ± SD	48.54 ± 9.46	50.75 ± 8.51	43.93 ± 8.70	48.90 ± 8.41	51.42 ± 11.02	1.786	0.164
Sex, n (%)							
Male	26 (54%)	7	7	6	6	0.124	0.945
Female	22 (46%)	5	7	4	6		
Medications, n							
Anti-hypertensive drugs	20 (44%)	4	5	4	7		
Anti-dyslipidemia drugs	19 (41%)	5	3	5	6		
Hypoglycemic drugs	7 (15%)	2	1	1	3		
Anthropometry, mean ± SD							
Height (cm)	165.57 ± 8.85	167.23 ± 8.19	164.24 ± 7.93	165.06 ± 8.92	165.90 ± 11.08	0.25	0.861
Weight (kg)	78.44 ± 13.59	79.31 ± 9.98	79.26 ± 12.39	73.64 ± 14.86	80.62 ± 17.31	0.535	0.66
Skeletal muscle mass (kg)	28.25 ± 6.37	28.49 ± 5.28	27.97 ± 5.96	27.31 ± 7.10	29.13 ± 7.76	0.155	0.926
Fat mass (kg)	27.54 ± 8.59	27.90 ± 8.63	28.93 ± 9.67	24.37 ± 5.99	28.18 ± 9.43	0.589	0.625
BMI (kg/m^2)	28.56 ± 4.34	28.52 ± 4.59	29.41 ± 4.65	26.85 ± 3.91	29.05 ± 4.20	0.736	0.536
Body fat (%)	34.95 ± 7.83	35.00 ± 8.46	36.21 ± 8.98	33.31 ± 5.91	34.80 ± 7.88	0.257	0.856
Waist circumference (cm)	97.01 ± 8.45	98.85 ± 5.24	97.68 ± 9.49	93.75 ± 9.38	97.13 ± 9.23	0.702	0.556
Hematology, mean ± SD							
Glucose (mg/dL)	100.23 ± 26.76	90.67 ± 28.54	113.64 ± 35.11	88.80 ± 10.75	103.67 ± 15.30	2.597	0.064
Triglycerides (mg/dL)	175.06 ± 80.71	197.42 ± 88.83	165.14 ± 71.49	194.30 ± 108.72	148.25 ± 49.43	1.009	0.398
HDL (mg/dL)	50.23 ± 10.46	46.33 ± 8.47	49.07 ± 11.04	52.10 ± 12.18	53.92 ± 9.69	1.234	0.309
Blood pressure (mmHg), mean ± SD							
Systolic	137.83 ± 14.90	137.17 ± 18.73	136.86 ± 15.93	138.10 ± 5.88	139.42 ± 16.28	0.07	0.976
Diastolic	85.96 ± 12.39	85.25 ± 12.45	86.50 ± 14.05	83.60 ± 8.00	88.00 ± 14.31	0.239	0.869

Mean±Standard Deviation. Abbreviations: Con = control group; DSW = consumption deep-sea water group; KMR = kinect-based mixed reality exercise group; DSW+KMR = consumption deep-sea water and Kinect-based mixed reality exercise group; BMI = body mass index; HDL = high-density lipoprotein.

Results

Primary Outcome

- **Waist circumference** Significant difference: Con vs KMR
- **MetS score** below MetS diagnose score (3 points)
- **Blood pressure** Significant differences within groups
- **Triglycerides, HDL, glucose** No significant differences

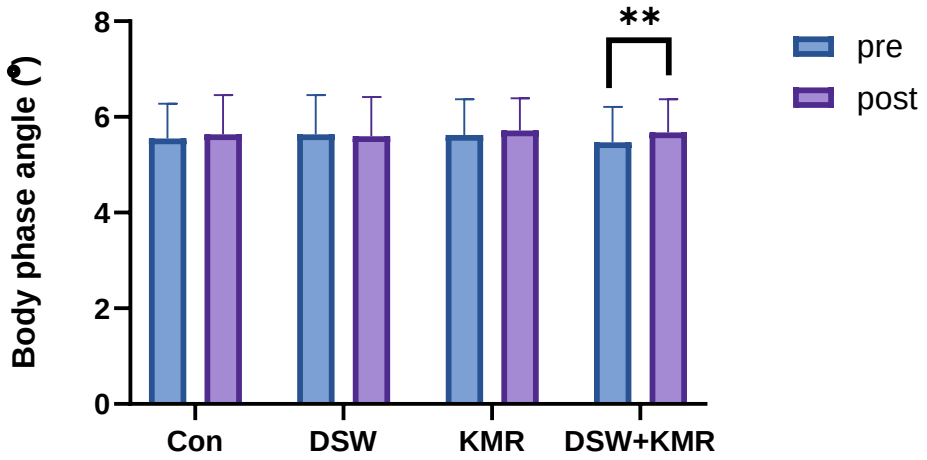


Characteristics	Con (n=12)		DSW (n=14)		KMR (n=10)		DSW+KMR (n=12)		*F*	*P*
	pre	post	pre	post	pre	post	pre	post		
Waist circumference (cm)	98.85 ± 5.24	98.17 ± 6.06	97.68 ± 9.49	93.93 ± 10.63**	93.75 ± 9.38	86.90 ± 11.04****	97.13 ± 9.23	91.38 ± 8.40****	4.635	**0.007**$^{\#\#}$
Triglycerides (mg/dL)	197.42 ± 88.83	167.00 ± 64.75	165.14 ± 71.49	175.07 ± 99.67	194.30 ± 108.72	151.40 ± 74.42	148.25 ± 49.43	129.25 ± 62.81	1.452	0.241
Glucose (mg/dL)	90.67 ± 28.54	91.08 ± 17.65	113.64 ± 35.11	107.79 ± 28.47	88.80 ± 10.75	87.90 ± 9.70	103.67 ± 15.30	97.67 ± 10.43	2.254	0.096
HDL (mg/dL)	46.33 ± 8.47	48.33 ± 7.23	49.07 ± 11.04	46.00 ± 14.14	52.10 ± 12.18	54.70 ± 15.69	53.92 ± 9.69	58.33 ± 15.15	1.806	0.161
Systolic blood pressure (mmHg)	137.17 ± 18.73	129.58 ± 13.43	136.86 ± 15.93	128.43 ± 11.84	138.10 ± 5.88	131.10 ± 7.91	139.42 ± 16.28	134.92 ± 14.19*	0.2	0.896
Diastolic blood pressure (mmHg)	85.25 ± 12.45	80.67 ± 9.75	86.50 ± 14.05	83.57 ± 11.38*	83.60 ± 8.00	83.20 ± 11.98	88.00 ± 14.31	81.33 ± 10.94	0.583	0.629
MetS score	3.73 ± 0.79	3.33 ± 1.15	3.64 ± 0.63	3.43 ± 0.85	3.50 ± 0.71	**2.60 ± 1.58**	3.75 ± 0.62	**2.83 ± 1.03**	1.826	0.157

Mean ± Standard Deviation. Values indicated are significantly different from baseline (pre) values. *p<.05, **p<.01, ***p <.001, ****p <.0001 different from baseline. #p<.05 between group difference. Abbreviations: Con = control group; DSW = consumption deep-sea water group; KMR = kinect-based mixed reality exercise group; DSW+KMR = consumption deep-sea water and Kinect-based mixed reality exercise group; HDL = high-density lipoprotein.

Results

Secondary outcome_body composition

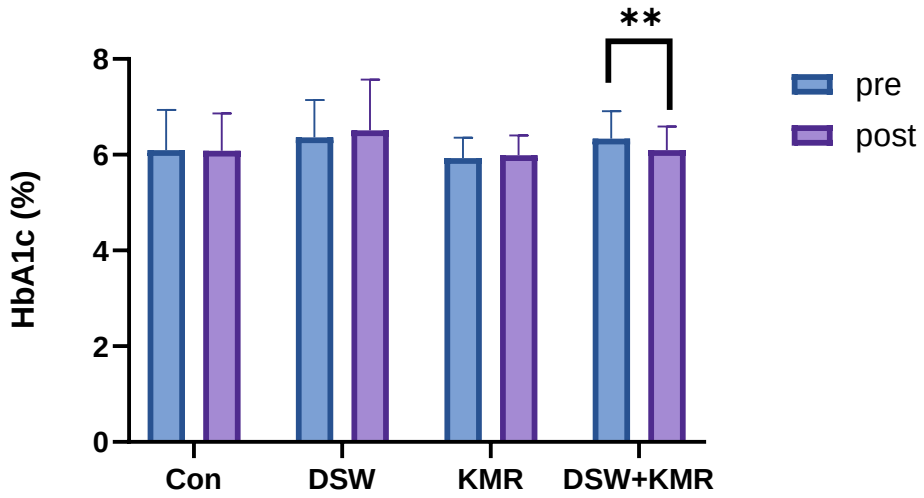


Characteristics	Con (n=12)		DSW (n=14)		KMR (n=10)		DSW+KMR (n=12)		*F*	*P*
	pre	post	pre	post	pre	post	pre	post		
Weight (kg)	79.31 ± 9.98	79.55 ± 10.02	79.26 ± 12.39	79.49 ± 13.36	73.64 ± 14.86	73.37 ± 15.10	80.62 ± 17.31	79.36 ± 18.12*	2.062	0.12
BMI (kg/m²)	28.52 ± 4.59	28.63 ± 4.50	29.41 ± 4.65	29.55 ± 4.91	26.85 ± 3.91	26.67 ± 4.13	29.05 ± 4.20	28.65 ± 4.22	1.971	0.133
Fat mass (kg)	27.90 ± 8.63	27.69 ± 8.85	28.93 ± 9.67	29.29 ± 10.54	24.37 ± 5.99	24.39 ± 7.05	28.18 ± 9.43	27.19 ± 8.82	1.276	0.295
Skeletal muscle mass (kg)	28.49 ± 5.28	28.76 ± 5.49	27.97 ± 5.96	27.88 ± 5.77	27.31 ± 7.10	27.19 ± 7.37	29.13 ± 7.76	29.03 ± 8.09	0.47	0.705
Body fat (%)	35.00 ± 8.46	34.64 ± 8.91	36.21 ± 8.98	36.39 ± 9.29	33.31 ± 5.91	33.44 ± 7.47	34.80 ± 7.88	34.16 ± 7.58	0.467	0.707
Body phase angle (˚)	5.55 ± 0.73	5.58 ± 0.80	5.64 ± 0.82	5.60 ± 0.82	5.62 ± 0.75	5.72 ± 0.67	5.47 ± 0.74	5.68 ± 0.69**	4.417	**0.009**##

Mean ± Standard Deviation. Values indicated are significantly different from baseline (pre) values. *p<.05, **p<.01 different from baseline. #p<.05, ##p<.01 between group difference. Abbreviations: Con = control group; DSW = consumption deep-sea water group; KMR = kinect-based mixed reality exercise group; DSW+KMR = consumption deep-sea water and Kinect-based mixed reality exercise group.

Results

Secondary outcome_blood analysis



Characteristics	Con (n=12)		DSW (n=14)		KMR (n=10)		DSW+KMR (n=12)		*F*	*P*
	pre	post	pre	post	pre	post	pre	post		
LDL Cholesterol (mg/dL)	104.58 ± 21.30	105.50 ± 25.45	123.43 ± 53.67	124.29 ± 53.98	114.70 ± 57.30	123.70 ± 63.55	113.17 ± 35.87	123.75 ± 36.93	0.581	0.631
Total cholesterol (mg/dL)	186.33 ± 27.15	181.25 ± 29.31	203.14 ± 61.82	195.36 ± 66.09	201.40 ± 58.14	203.10 ± 69.73	191.17 ± 48.01	199.92 ± 50.00	1.298	0.288
HbA1c (%)	6.10 ± 0.84	6.08 ± 0.74	6.36 ± 0.78	6.51 ± 1.06	5.93 ± 0.43	5.99 ± 0.41	6.34 ± 0.57	6.10 ± 0.49**	4.049	**0.013**$^{\#}$

Mean±Standard Deviation. Values indicated are significantly different from baseline (pre) values. *p<.05, **p<.01, ***p <.001 different from baseline. #p<.05 ##p <.01 between group difference. Abbreviations: Con = control group; DSW = consumption deep-sea water group; KMR = kinect-based mixed reality exercise group; DSW+KMR = consumption deep-sea water and Kinect-based mixed reality exercise group; BMI = body mass index.

Discussion

This study is the first study the effects of Kinect-based mixed reality(KMR) exercise and deep-sea water(DSW) consumption on metabolic syndrome(MetS).

Utilizing motion detection technology, participants received real-time feedback, and drink DSW in significant **reduction in waist circumference.**

The observed reduction in waist circumference is critical, as it serves as a key predictor for MetS and cardiovascular risk (Ranasinghe et al., 2017).

Both the KMR group and the DSW+KMR group reduced their metabolic syndrome diagnostic scores to below the threshold of 3 points. This indicates a significant improvement in their metabolic health status, effectively reclassifying them away from being categorized as having metabolic disease.

Conclusion

- Significant improvements in waist circumference and metabolic syndrome factor scores were found
  - KMR + DSW combination could be a non-pharmacological strategy for MetS management

Acknowledgements

SoYoung Ahn PhDc
STUDY I

Hyejung Shin MSc
STUDY II

Thanks to our lab members