Master's Thesis

Association of Emotional State and Body Composition with Gait Patterns

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ABSTRACT

Walking is an important element of various daily life activities. Walking can be the simplest indicator that can quantitatively characterize an individual's condition. To predict information about people based on their walk, multiple factors that influence walking have been researched. The factors could be divided into cognitive state and physical state. Therefore, this study selected emotional state and body composition as the main factors affecting walking to determine each of the two influences.

In previous studies, the effect of emotional state and body composition was measured using a motion capture analysis or a force plate. However, identifying emotions and body composition through motion capture analysis requires sensors to be attached to a person and cannot be done in a noisy environment. As a result, it is impossible to find out the state of emotions and body composition through motion capture analysis in public places such as streets or shopping malls. Therefore, research into how a pressure platform can predict emotional state and body composition because a pressure platform does not need any sensors attached to the body and can be installed hidden.

Forty-seven participants (24 men, mean 21.8 years, SD 2.3 years; 23 women, mean 22.2 years, SD 3.3 years) were recruited for this study. Before the main experiment, their body composition was measured in the morning by Inbody 570, which uses direct segmental multi-frequency bioelectrical impedance analysis. In the main experiment, the participants performed four walking tasks. One was a natural walking task, and the others were the emotional walking tasks (sadness, neutral, and joy). Two-minute video clip-based stimuli were used to induce emotions. During the tasks, the participants walked barefoot on the 10 m walkway with an installed pressure platform back and forth. While walking, the gait patterns described by spatiotemporal parameters, diagram of the center of pressure (CoP), and force and pressure of foot were measured. After the tasks, the intensity of valence, arousal, and physical activity were measured by the two questionnaires.

The analyses were conducted separately into men and women. Repeated ANOVA with Tukey post-hoc analyses was performed to examine the effect of emotions on gait patterns measured during the emotional walking tasks. Pearson correlation and multiple linear regression analyses were performed to determine the effect of body composition on the gait patterns measured during the natural walking task.

According to the intensity of valence, gait patterns were changed. Walking feeling joy increased stride length, cadence, and velocity and decreased step time. With increased walking speed, the percentage of stance phase and double support phase were reduced, and the swing phase was longer during a whole gait cycle. The length of the CoP path during the single support phase was increased. The first peak force and the second peak force during 100% of the gait cycle increased, and time to the first peak reduced. In the only men, less mediolateral displacement of the CoP intersection point was presented.

In the men, height and right leg fat-free mass had a commonly positive correlation with stride length, walking speed, and length of the CoP path during the stance phase and the single support phase. They had a negative correlation with the anteroposterior of the CoP intersection point. Weight presented a strong correlation with a maximum force of forefoot and heel and was moderately correlated with midfoot. As the total and segmental fat mass increased, the maximum force of forefoot, midfoot, and heel increased similar to weight. The body mass index (BMI) was correlated with a maximum force of forefoot and midfoot. In the regression prediction model, total and segmental fat mass (right arm, trunk, and right leg fat mass) were indirectly predicted by decrease in two CoP variables, mediolateral displacement of CoP intersection point and length of CoP path during stance phase with a direct effect of increased maximum force of right forefoot and right midfoot. Total and segmental fat-free mass (right arm, trunk, and right leg fat mass) were indirectly predicted by the length of the CoP path during the stance phase and maximum force with the direct effect of decreased contact time of right heel.

Contrary to the men, height and total fat-free mass were correlated with weight in the women. Weight was correlated with the maximum force of forefoot and heel. The maximum force of midfoot did not show the correlation with body composition. Weight, BMI, and total and segmental fat mass, which were intercorrelated with each other, were correlated with the contact time of forefoot and midfoot. In the regression prediction model, the direct effect predicted most of the fat mass and fat-free mass. Total and segmental fat mass were predicted by a decrease in length of CoP during the right single support phase and an increase in the maximum force of forefoot, while total and segmental fat-free mass were predicted by an increase in the maximum force of forefoot.

This study will help to understand the relationship between emotion and body composition on gait patterns. It will be the basis for developing models to predict an individual's emotional state and body composition using a pressure platform, and further to provide personal information that can be used in marketing.

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EXPLANATION OF TERMS AND ABBREVIATIONS

BMI	Body mass index
BFM	Total fat mass
FFM	Total fat-free mass
BFM_RA	Right arm fat mass
BFM_TR	Trunk fat mass
BFM_RL	Right leg fat mass
FFM_RA	Right arm fat-free mass
FFM_TR	Trunk fat-free mass
FFM_RL	Right leg fat-free mass
G_STL	Step length
T_ST	Step time
G_SRL	Stride length
T_SR	Stride time
P_ST	Stance phase
P_SW	Swing Phase
P_DS	Double support phase
T_C	Cadence
T_V	Walking speed
LoG	Length of the butterfly diagram during stance phase
LoS	Length of the butterfly diagram during single support phase
AP_SD	Anteroposterior displacement of CoP intersection point
ML_SD	Mediolateral displacement of CoP intersection point
M1	The 1st peak force of average gait cycle
M2	The 2nd peak force of average gait cycle
TM1	Time to the 1st peak force.
TM2	Time to the 2nd peak force.
MF_F	Maximum force of forefoot
MF_M	Maximum force of midfoot
MF_H	Maximum force of heel
C_F	Contact time of forefoot
C_M	Contact time of midfoot
C_H	Contact time of heel

1. INTRODUCTION

Walking is an important element of various daily life activities. Walking can be the simplest indicator that can quantitatively characterize an individual's condition. For this reason, studies have been conducted looking for numerous factors that influence walking to identify individuals by analyzing their gait. Walking is primarily affected by two things: the cognitive and the physical state. In this study, to determine each of the two influences, emotional state and body composition were considered as the main factors affecting walking.

1.1 Effect of emotional state on gait

For a long time, human behavior movements have been considered to convey emotional-related information. Since Darwin first described the effects of emotions on movement behavior, many studies have been conducted on the relationship between emotions and behavioral changes. The studies ranged from qualitative research that observe changes in body movements after getting actors to play certain emotions to quantitative research using a motion capture analysis or a force platform to find biomechanical factors influenced by emotional state. Moreover, as the recent development of machine learning technologies, it has allowed us to find out their emotions by analyzing the video of people walking.

1.1.1 Previous research using a motion capture analysis

In the study of Kang and Gross (2015), they asked the participants to write the autobiography to induced target emotions. They used jerk normalized by stride time and movement distance to calculate movement smoothness. According to their result, relative to neutral emotion, sadness decreased peak forward center of mass (CoM) velocity, peak vertical CoM velocity and movement smoothness with increased phase duration and joy increased peak forward CoM velocity, peak vertical CoM velocity and movement smoothness with decreased phase duration during sit-to-walk task. They also studied while walking tasks with the same methods inducing emotions (Kang & Gross, 2016). It showed joy changed the variables associated with an increased walking speed such as stride length, cadence, stride time. Besides, joy increased vertical movement smoothness of CoM, head, thorax, and pelvis and anteroposterior movement smoothness of head compared to sadness.

In another study, the researchers used music to induce the target emotions. While walking, sad emotion caused by listening to music decreased walking speed, arm swing, and vertical head movement and increased lateral sway in upper body movement with more slumped posture (Michalak et al., 2009).

Recent studies have identified the effects of emotion, taking into account familiarity. When the participants listened to pleasant music, walking speed, stride length, and cadence increased and stride length decreased. The impact only appeared when they listened to familiar music (Park, Hass, Fawver, Lee, & Janelle, 2019).

Barliya et al. (2013) studied the effect of emotions on kinematic properties of leg movement with intersegmental coordination. They had required participants to recall memories related to the target emotion of the past situation. As a result, they found decreased stance phase and increased swing phase for joy compared to sad emotion. Furthermore, they more focused on the effect of walking speed because the walking speed may be a confounder effect on kinematic change. To cancel out the effect of speed, they used the regression model and analyzed the residual effects of emotion on gait patterns. The result showed increased amplitudes of thigh, shank, and foot elevation in joy emotions compared to sadness as the effect of emotion than walking speed.

1.1.2 Previous research using a force platform

During static stance, unpleasant auditory stimuli increased anteroposterior range of center of pressure (CoP) in adults (Chen & Qu, 2017). Similarly, Brandão et al. (2016) researched the effect of emotions on the CoP deviation. In the research, video stimuli were used to caused sadness emotion. The participants maintained a static stance while watching the video stimuli. The change in postural sway of the CoP had the same trend with the change in intensity of arousal, and it showed a significant difference between low arousal (neutral stimulus) and high arousal (unpleasant and pleasant stimuli). Higher arousal increased mediolateral and anteroposterior postural sway.

During gait initiation, posterior CoP displacement and step velocity was decreased after viewing affective picture of low arousing unpleasant (sadness) and increased in higher arousing pleasant (joy). It indicated approach-related movement with promoting gait initiation (Naugle, Hass, Joyner, Coombes, & Janelle, 2011). Beatty et al. (2014) also studied the CoP displacement but they more focused on the time before the gait initiation. They also used affective pictures to induced emotion. As a result, posterior postural response was presented to all stimuli and posterior CoP displacement was reduced in joy emotion compared with neutral stimuli, which was inconsistent with change during gait initiation.

However, the number of studies regarding energy variables was limited. Kang et al. (2018) quantified activity and energy variables during gait with various phases of bipolar disorder to study the effect of mood on gait patterns. They analyzed the gait patterns of individuals with bipolar disorder (hypomanic, euthymic, and depressed) and healthy controls using the motion capture analysis and the force platform. Bipolar disorder was characterized using a Patient Health Questionnaire and the Altman

Self Rating Mania Scale. The hypomanic group showed increased gait speed, stride length, and cadence. They produced greater peak braking force, push-off force, and vertical force and generated higher peak knee and ankle power during gait while the depressed group showed decreased gait speed, stride length, and cadence with less force and power.

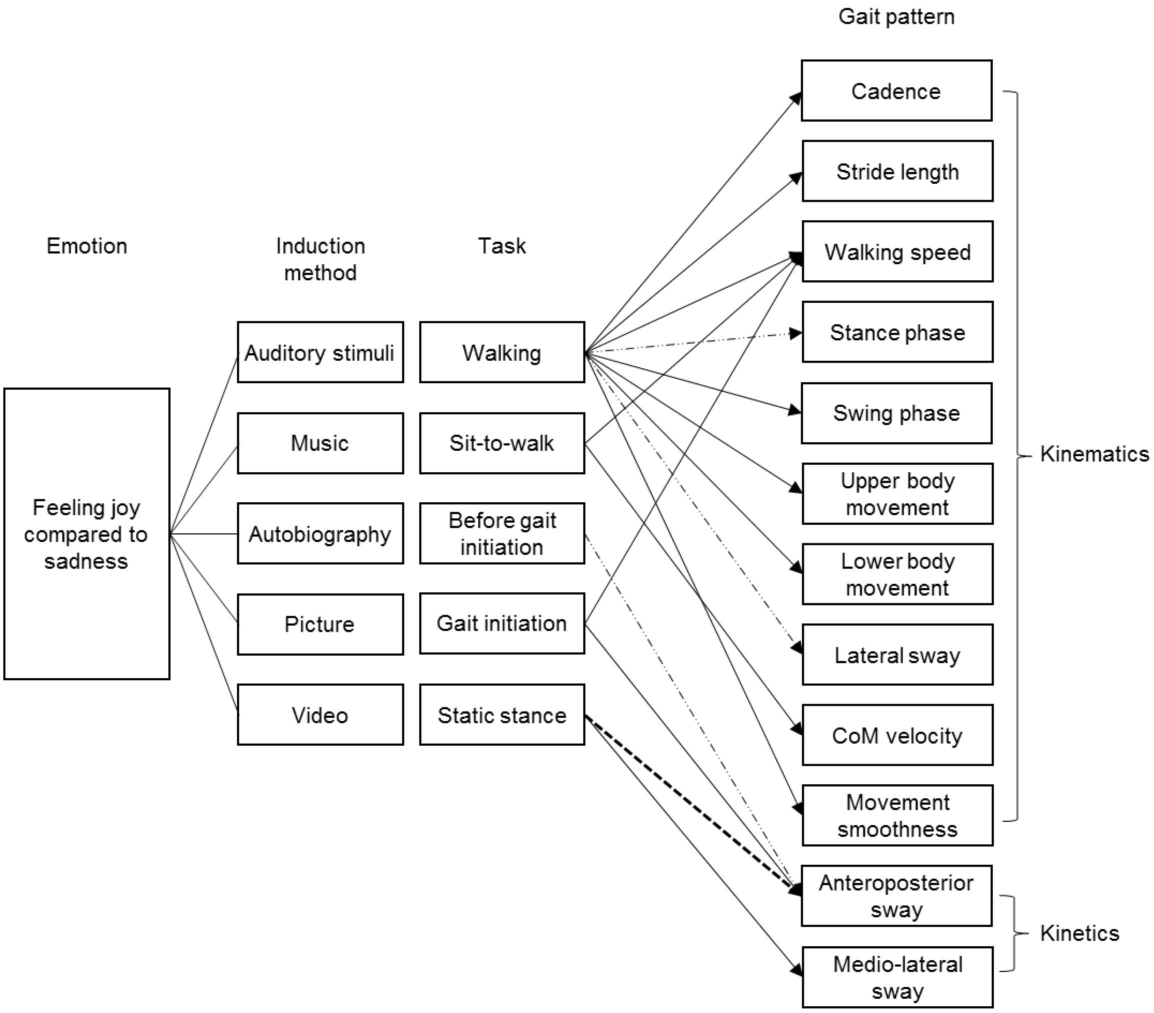


Figure 1. A schematic diagram of the previous studies regarding effect of emotion (joy vs. sadness) on gait patterns.

The Solid line means a positive impact; the Dotted line indicates a negative impact; the Bold dotted line means a controversial relationship.

1.2 Effect of body composition on gait

Body composition is an important indicator of body function. High total fat mass and low total fat-free mass negatively affect body function, which also affects walking. Therefore, it is important to know how the body composition is distributed according to each part and how it affects to change in gait patterns. However, most of the research on the change in walking patterns based on body composition focused on height, weight and body mass index (BMI).

1.2.1 Previous research

The effect of height and body weight on walking speed, stride length and cadence of women and men was studied using force platform (Samson et al., 2001). Participants (118 women and 121 men) walked at preferred speed over the walkway. Bivariate regressions were conducted. The result showed that increased height explained the increase in walking speed (r^2=0.110 for women; r^2=0.294 for men) and stride length (r^2=0.294 for women; r^2=0.221 for men), weight was not affected by the change in gait parameters. Cadence was not associated with age, height, and body weight.

Chiari et al. (2002) researched the effect of body composition on stabilometric parameters using a force platform during static stance with 25 women and 25 men. They conducted maximum-likelihood robust regression analysis with selected features such as height and weight, which were from Principal Component Analysis. Height was associated with mediolateral and anteroposterior sway path (length of CoP path), range of CoP displacement, and mean velocity of CoP. Weight was associated with mediolateral and anteroposterior sway path and mean velocity of CoP.

Alonso et al. (2012) studied the influence of body composition (weight, height, length of trunk-cephalic region, length of lower limb and upper limb, fat percentage, tissue mass, fat mass, lean mass, bone mineral content, bone mineral density, BMI, waist-hip ratio and the support base area) and gender on postural control using posturography variables. Fifty men and fifty women participated in an experiment. They conducted multiple linear regression analyses and found that mediolateral displacement, sway velocity, and displacement area increased as height increased (r^2=0.12 and r^2=0.11, respectively), and the anteroposterior displacement increased as trunk-cephalic length increased (r^2=0.06) during postural balance test in the whole gender.

The same research group suggested that men and women were differently affected by body composition (A. C. Alonso et al., 2015). They measured similar body composition with the previous study: weight, height, length of trunk-cephalic region, length of lower limb and upper limb, fat percentage, tissue mass, fat mass, lean mass, bone mineral content, bone mineral density, BMI and the support base area. The correlation analysis and multiple linear regression model were used to determine the relationship between body composition and postural sway during the postural balance test. They discovered that the effect of body composition on body sway was only presented in men. For men, increased height and decreased support base area explained increased mediolateral sway of CoP, increased lean mass explained anteroposterior sway of CoP and increased lean mass and decreased support base area explained decreased CoP area (r^2=0.28, r^2=0.10, and r^2=0.25, respectively).

In the study of changes in gait patterns in obese young women (da Silva-Hamu et al., 2013), 24 obese (mean BMI=31.85 kg/m^2) and 24 eutrophic women (mean BMI=21.82kg/m^2) were recruited. Obese women presented shorter step and stride length, walking speed, and cadence with the delayed angular movement of ankle join in almost of the gait cycle.

Another study researched the relationship between BMI and knee biomechanics (Freedman Silvernail, Milner, Thompson, Zhang, & Zhao, 2013). The participants (15 women and 15 men) were divided into three groups: normal weight (BMI<25), overweight (25<BMI<30), and obese (BMI>30). The participants walked across the 10m overground walkway. While walking with preferred speed, the gait patterns were measured with force plates and motion capture analysis. Obese participants showed decreased walking speed than normal-weight participants. There were no differences in knee biomechanics such as knee flexion excursion, peak knee flexion angle, and normalized peak knee flexion and adduction moment according to BMI.

Higher BMI changed dynamic posterior stability (do Nascimento, Silva, Dos Santos, de Almeida Ferreira, & de Andrade, 2017). The obese group (3 men; 12 women; Mean BMI=35.65) showed postural shifts such as hyperkyphosis and asymmetry with elevation to the left and they showed poor dynamic posture stability which was measured by Biodex Balance System compared to normal-weight group (2 men; 8 women; Mean BMI = 21.50).

Recently, two studies have been conducted on how segmental fat mass and total fat-free mass affect gait patterns (Y.G. Lee & Shin, 2018; Villarrasa-Sapiña et al., 2018). Lee and shin (2018) recruited 33 young adults and used the bioelectrical impedance method and inertia sensor to measure body composition and gait patterns, respectively. The participants walked over 400m track at preferred walking speed. Pearson correlation and multiple linear regression analysis were conducted to analyze the effect of body composition on gait patterns. Total fat mass, total fat-free mass, BMI, and segmental fat-free mass (arm, upper body, and lower body) were measured as body composition. Cadence, stride time, temporal parameters, spatial parameters, and foot kinematics such as max heel clearance, max toe clearance, and toe-off pitch were measured to describe gait patterns. According to Pearson correlation, total fat mass was positively correlated with the pushing phase and peak swing. Total fat-free mass was positively correlated with cadence, stride time, foot flat phase, and stride length and negatively correlated with the push-off phase. Segmental fat-free mass also presented a similar tendency with total fat-free mass, but arm fat-free mass was not correlated with the foot-flat phase, and stride length and lower body fat-free mass were not correlated with foot-flat phase. In the regression model, height and lower body fat-free mass was a significant predictor of stride length and max heel clearance, respectively.

Villarrasa-Sapiña et al. (2018) conducted the experiment with 22 children (mean age=12.04) to find an effect of body composition on postural control. A force plate measured postural control during static stance. They performed principal component analysis, then multiple linear regression analysis. As a result, they found that height and leg mass were correlated with postural control and leg mass and trunk mass were better predictors of postural control than other body composition mass.

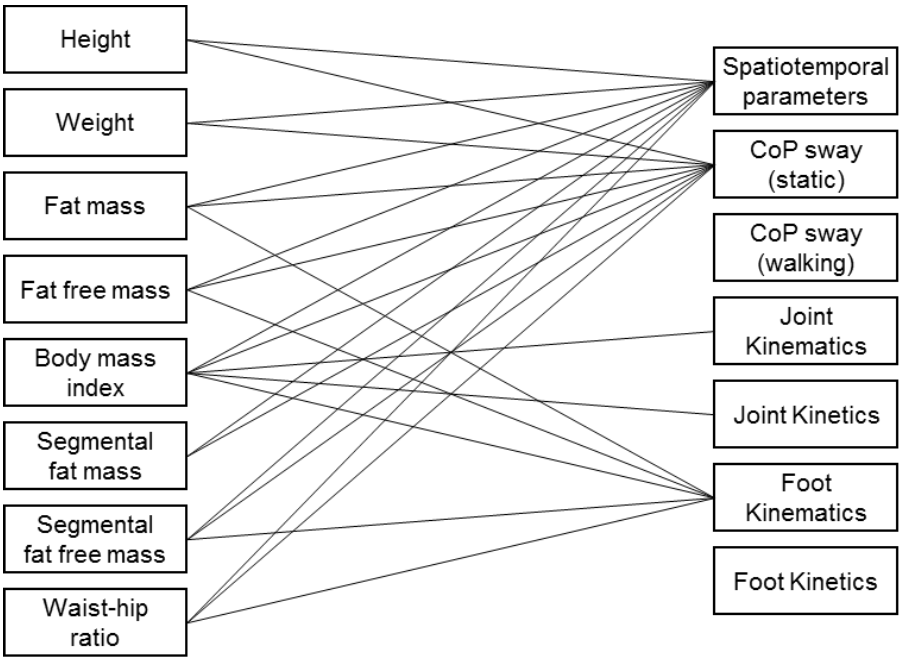


Figure 2. The relationship between body composition and gait patterns.

A solid line between the two variables means that previous studies related to the two variables have been conducted.

1.3 Research objectives

In summary, as shown in Figure 1 and Figure 2, the research about association of emotional state and body composition with plantar pressure distribution was still limited. Identifying emotions and body composition through motion capture analysis requires sensors to be attached to a person and cannot be done in a noisy environment. As a result, it is impossible to find out the state of emotions and body composition through motion capture analysis in public places such as street or shopping malls. Conversely, using a pressure platform to obtain information about emotions and physical components provides an opportunity to recognize human emotions and body composition because it does not need any sensors attached to the body, and it also can be installed unnoticed. Therefore, it should be needed to research how emotional state and body composition on gait patterns using a pressure platform.

This study aimed to investigate the effects of emotional state and body composition on gait patterns described by spatiotemporal gait parameters, CoP butterfly parameters, plantar force, and pressure. The emotional state was composed of three: sadness, neutral, and joy. The body composition was height, weight, body mass index (BMI), total fat mass (BFM), total fat-free mass (FFM), segmental BFM, and segmental FFM. The segmental BFM and FFM were calculated into five segments; right arm (RA), left arm (LA), trunk (TR), right leg (RL), and left leg (LL).

2. METHOD

2.1 Participants

Forty-seven participants (24 men, mean 21.8 years, *SD* 2.3 years; 23 women, mean 22.2 years, *SD* 3.3 years) were recruited from the university community. Participants had no problem walking for more than half an hour. Individuals with musculoskeletal disease, or plantar wounds, and intra-body metal implants were excluded from this experiment. Before participating, each participant provided consent on a protocol approved by the university's institutional review board.

2.2 Instruments (FDM, Inbody 570)

2.2.1 Pressure measurement system

The Zebris pressure platform (Zebris FDM 1.5; ZEBRIS Medical, Isny, Germany) was used to record foot pressure (Figure 3). The pressure platform (158 x 60.5 x 2.5 cm (L x W x H)) had 11264 sensors in sensor area (149 x 54 cm (L x W)). It was located 3.75m from the start line of a 10.35m walkway, which had sufficient distance for the participants to walk naturally. The walkway, including the pressure platform, was covered with black paper sheets so that the participants did not know the information about the measurement location (Figure 4).

For data acquisition, the Zebris FDM Software V1.16.12 (ZEBRIS Medical, Isny, Germany) was used. The pressure data were collected at 100Hz sampling frequency. The software provided the information of gait patterns by calculating ground reaction force: spatiotemporal gait parameters, center of pressure (CoP) analysis, force and pressure parameters, and three-foot zone analysis with force, pressure and contact time of forefoot, midfoot and heel (Figure 5 and Figure 6).

Figure 3. The Zebris pressure platform.

Figure 4. The setting of the Zebris pressure platform located in walkway.

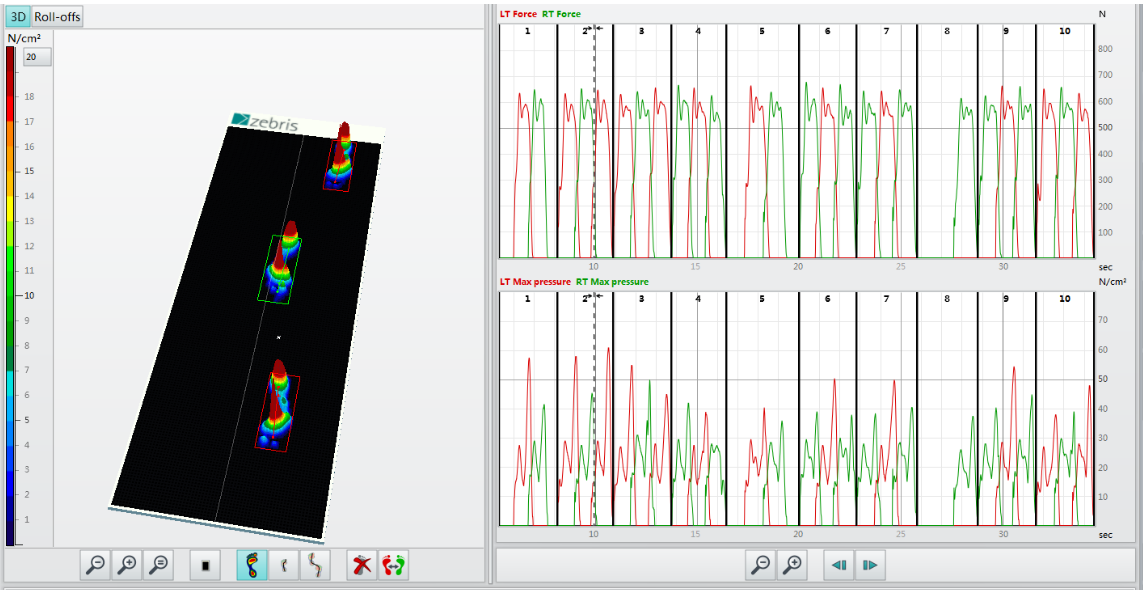


Figure 5. Pressure and force distribution in the Zebris FDM Software.

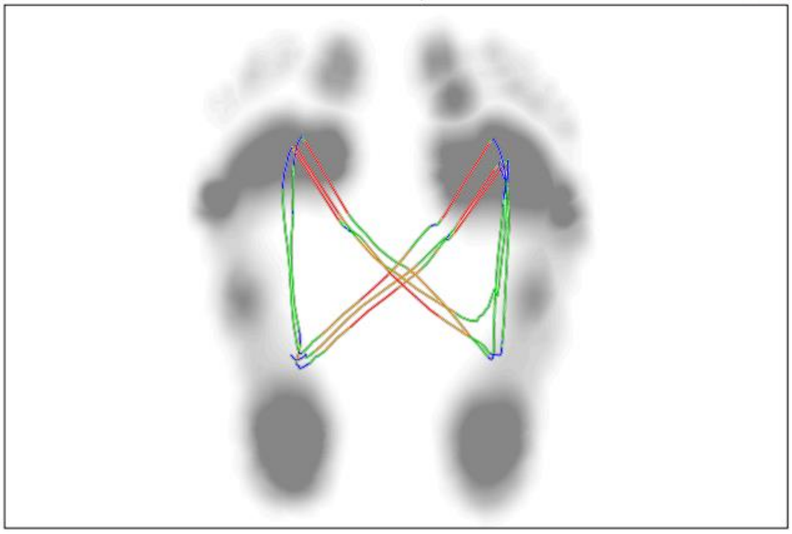
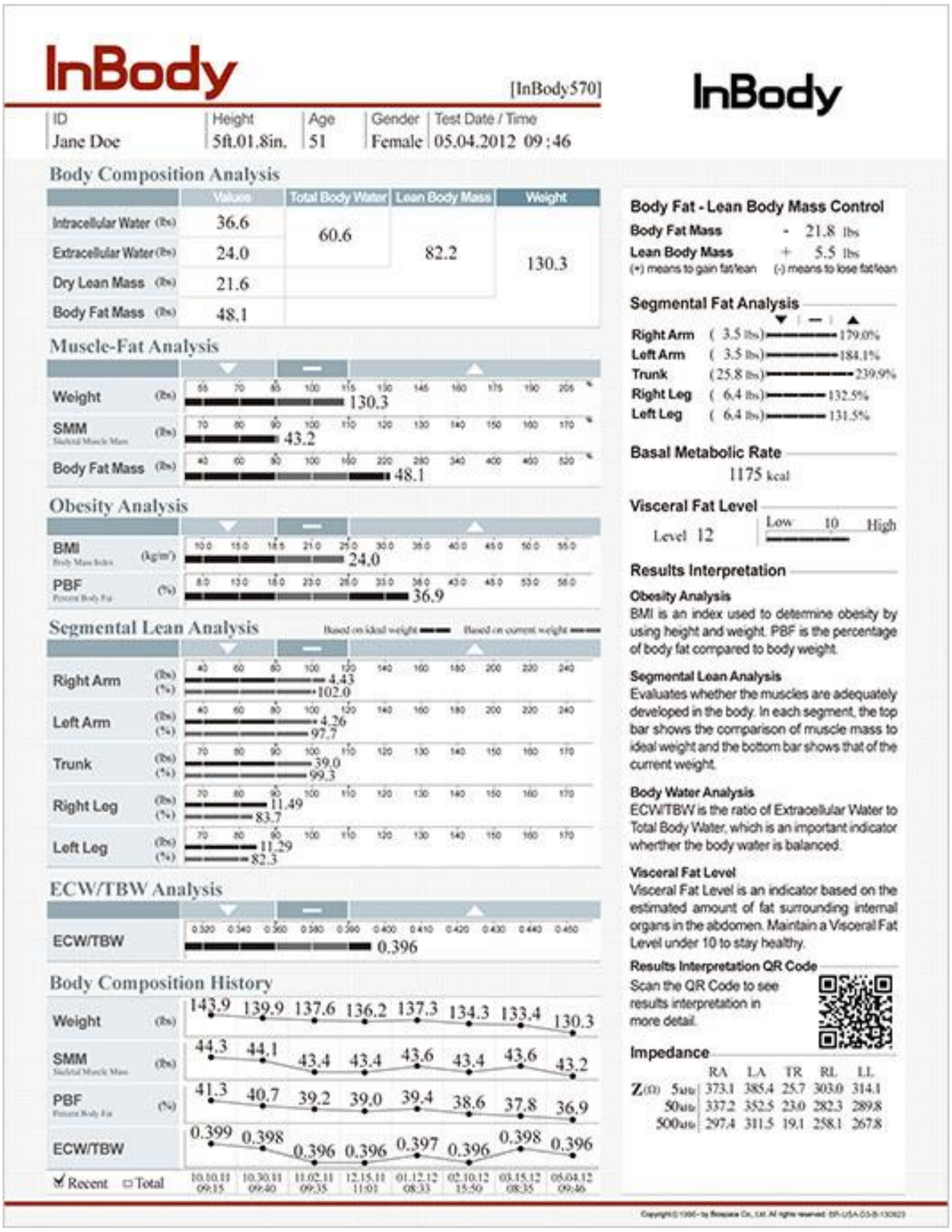


Figure 6. Butter diagram of CoP path in the Zebris FDM Software.

2.2.2 Body composition measurement system

Body composition parameters were measured by Inbody 570 (Biospace, Inc Seoul, Korea), which uses direct segmental multi-frequency bioelectrical impedance analysis (Figure 7). It measures 15 impedance in each of the five areas (right arm, left arm, trunk, right leg, and left leg) in the three frequency (5 kHz, 50 kHz, and 500 kHz). By bioelectrical impedance analysis, it provided body composition parameters such as body water, protein, mineral, total, and segmental amount of fat and fat-free mass and circumference of each segment (Figure 8).

Figure 7. Body composition analyzer, Inbody 570.



InBody [InBody570]

InBody

ID	Height	Age	Gender	Test Date / Time
Jane Doe	5ft.01.8in.	51	Female	05.04.2012 09 : 46

Body Composition Analysis

	Values	Total Body Water	Lean Body Mass	Weight
Intracellular Water (lbs)	36.6	60.6	82.2	130.3
Extracellular Water (lbs)	24.0			
Dry Lean Mass (lbs)	21.6			
Body Fat Mass (lbs)	48.1			

Muscle-Fat Analysis

		▼	—	▲
Weight	(lbs)	130.3		
SMM Skeletal Muscle Mass	(lbs)	43.2		
Body Fat Mass	(lbs)	48.1		

Obesity Analysis

		▼	—	▲
BMI Body Mass Index	(kg/m²)	24.0		
PBF Percent Body Fat	(%)	36.9		

Segmental Lean Analysis Based on ideal weight ▬▬ Based on current weight ▬▬

		▼	—	▲
Right Arm	(lbs) (%)	4.43 102.0		
Left Arm	(lbs) (%)	4.26 97.7		
Trunk	(lbs) (%)	39.0 99.3		
Right Leg	(lbs) (%)	11.49 83.7		
Left Leg	(lbs) (%)	11.29 82.3		

ECW/TBW Analysis

	▼	—	▲
ECW/TBW	0.396		

Body Composition History

Weight	(lbs)	143.9	139.9	137.6	136.2	137.3	134.3	133.4	130.3
SMM Skeletal Muscle Mass	(lbs)	44.3	44.1	43.4	43.4	43.6	43.4	43.6	43.2
PBF Percent Body Fat	(%)	41.3	40.7	39.2	39.0	39.4	38.6	37.8	36.9
ECW/TBW		0.399	0.398	0.396	0.396	0.397	0.396	0.398	0.396
☑ Recent	☐ Total	10.10.11 09:15	10.30.11 09:40	11.02.11 09:35	12.15.11 11:01	01.12.12 08:33	02.10.12 15:50	03.15.12 08:35	05.04.12 09:46

Body Fat - Lean Body Mass Control

Body Fat Mass	-	21.8 lbs
Lean Body Mass	+	5.5 lbs

(+) means to gain fat/lean (-) means to lose fat/lean

Segmental Fat Analysis ▼ — ▲

Right Arm	(3.5 lbs)	179.0%
Left Arm	(3.5 lbs)	184.1%
Trunk	(25.8 lbs)	239.9%
Right Leg	(6.4 lbs)	132.5%
Left Leg	(6.4 lbs)	131.5%

Basal Metabolic Rate

1175 kcal

Visceral Fat Level

Level 12

Results Interpretation

Obesity Analysis
BMI is an index used to determine obesity by using height and weight. PBF is the percentage of body fat compared to body weight.

Segmental Lean Analysis
Evaluates whether the muscles are adequately developed in the body. In each segment, the top bar shows the comparison of muscle mass to ideal weight and the bottom bar shows that of the current weight.

Body Water Analysis
ECW/TBW is the ratio of Extracellular Water to Total Body Water, which is an important indicator wherther the body water is balanced.

Visceral Fat Level
Visceral Fat Level is an indicator based on the estimated amount of fat surrounding internal organs in the abdomen. Maintain a Visceral Fat Level under 10 to stay healthy.

Results Interpretation QR Code
Scan the QR Code to see results interpretation in more detail.

Impedance

Z(Ω)	RA	LA	TR	RL	LL
5kHz	373.1	385.4	25.7	303.0	314.1
50kHz	337.2	352.5	23.0	282.3	289.8
500kHz	297.4	311.5	19.1	258.1	267.8

Figure 8. Example result sheet from body composition analyzer, Inbody 570.

(Retrieve from http://inbody.com/eng/product/inbody570.aspx)

2.3 Experiment design

2.3.1 Experiment variables

This experiment was designed with multivariate variables. The variables were emotional state, emotional response, the intensity of physical activity, body composition, and gait parameters.

The stimuli which induce three emotions were tested in this experiment: joy (high valence and high arousal), sadness (low valence and low arousal), and neutral. A two-minute video clip-based stimulus was used to induce emotions. Among 32 video stimuli, the two video clips of each emotion (joy and sadness) were selected based on survey result of the previous study which was conducted by 60 participants (30 men, mean 29.0 years, *SD* 3.2 years; 30 women, mean 28.7 years, *SD* 3.9 years) (Kwon, Kim, Park, & Kim, 2016). Then, through interviews with the university students, one stimulus of each emotion was finally selected for the experiment.

Emotional responses were each obtained by a graphic questionnaire. Emotional valence and arousal were quantified by using the 9-point graphic scales of the Self-Assessment Manikin (SAM) questionnaire (Figure 9), which directly measures affective reaction to stimuli (Bradley & Lang, 1994). Valence was the level of joy that a stimulus brings, from sadness to joy. Arousal was the level of self-activation that the stimulus generates, from calm to excitement.

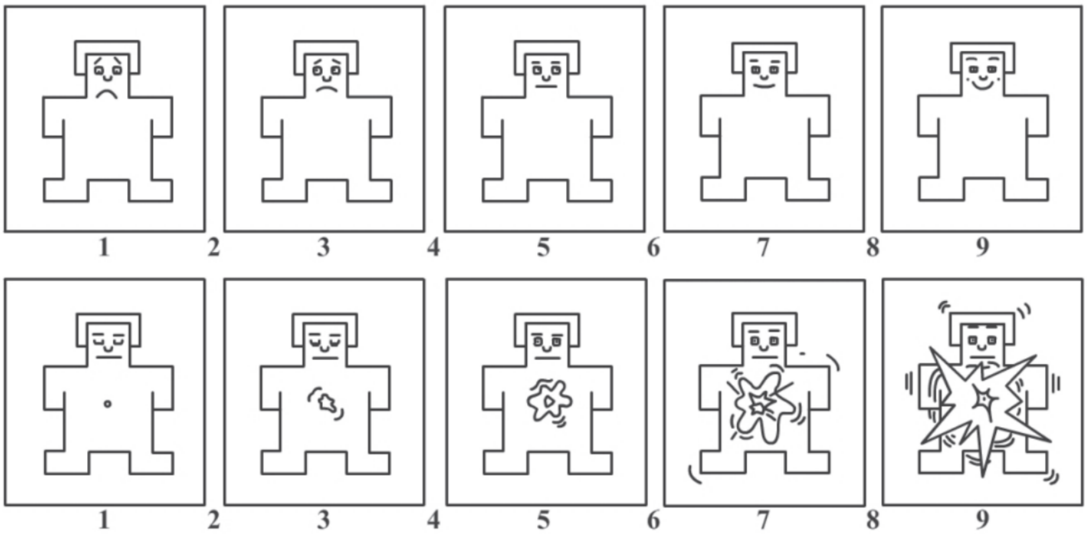


Figure 9. The SAM used to the affective reaction of valence (top) and arousal (middle)

The Korean version of Global Physical Activity Questionnaire (K-GPAQ) was used in this experiment (*Development of the Korean Version of Global Physical Activity Questionnaire and Assessment of Reliability and Validity*, 2013). The GPAQ was developed by the World Health Organization (Armstrong & Bull, 2006) and used to measure the personal intensity of physical activity. The GPAQ consists of questions about four categories (work-related activities, the way of travel to and from places, recreational activities, and sedentary behavior). In each category, questionnaires asking the frequency and time of each activity were contained. Table 1 contained the contents of the GPAQ.

The variables of body composition used were height, weight, body mass index (BMI), total fat mass (BFM), total fat-free mass (FFM), segmental BFM, and segmental FFM. The segmental BFM and FFM were calculated into five segments; right arm (RA), left arm (LA), trunk (TR), right leg (RL), and left leg (LL).

The gait parameters were descripted in Table 2.

2.3.2 Experimental procedures

The overall procedure was described in Figure 10. On the morning of the experiment, participants visited the laboratory on an empty stomach to measure the body composition. Before measurement, they stood on the machine with barefoot and were instructed to hold the electrodes with their arms stretched out, keeping their arms and thighs not touched (Figure 12-A). They maintained instructed posture until the end of the measurement of the body composition for the accurate result.

The experiment was conducted in the classroom where the sunlight was blocked, and the window was covered with black paper to minimize environmental distraction. In the experiment, the participants performed four walking tasks. One was a natural walking task, and others were the emotional walking tasks. During the tasks, the participants walked barefoot on the 10 m walkway back and forth (Figure 12-B). They were only instructed not to turn too fast on either end of the walkway, but they were not instructed to do anything that could affect their walking patterns, such as eyesight or arm movement, so that they could walk as naturally as possible.

Participants performed the natural walking task at the beginning of the experiment. The participants walked on the walkway back and forth for 2 minutes. After natural walking, the participants performed three tasks of emotional walking. Among the three emotional walking tasks, the participants always performed the neutral task first then performed the joys and sadness task in a randomized order. The participants were standing in front of the walkway and looking at the monitor as comfortably as possible. They focused on a fixation cross for two seconds before watching the stimulus. The participants watched the video clip-based stimuli through the monitor and listened to the sound stimuli through the speakers placed on the monitor (Figure 12-C). When the video stimulus was turned off, they walked along the walkway immediately. While walking, they recalled the video and felt emotions. Between each emotional walking task, participants played word-for-word game (MOBIRIX, 2015) for 3 minutes to wash out the previous emotion (Figure 11).

Before and after emotional walking task, they rated their own levels of valence and arousal on the scale of the 9-point SAM graphic scales: valence before the task (V_{before}), valence after the task (V_{after}), arousal before the task (A_{before}), and arousal after the task (A_{after}). After all the tasks, the participants responded to each question in the K-QPAQ. When responding to the K-QPAQ, they were guided to read all the examples on the questionnaires then respond to the questionnaire by reminding their usual week. They used an iPad to respond to the questionnaire given as a Google survey. To make the participants feel comfortable while responding to the questionnaire, they were apart from the experimenter's seat where the experimenter did not pay attention to the participants (Figure 12-D).

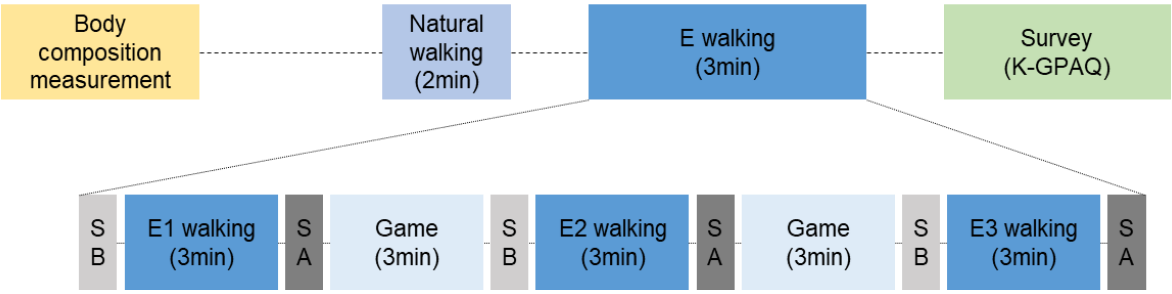


Figure 10. Overall procedure of the experiment. E: Emotional walking.
SB: Survey before task. SA: Survey after task.

캄	보	디	아	배	디	의
력	작	환	자	기	압	견
꽃	상	추	전	호	이	의
와	에	다	허	분	로	차
달	이	버	주	리	기	이
빅	파	득	자	아	케	관
인	명	위	내	유	결	인

Figure 11. Example of a word-for-word game.

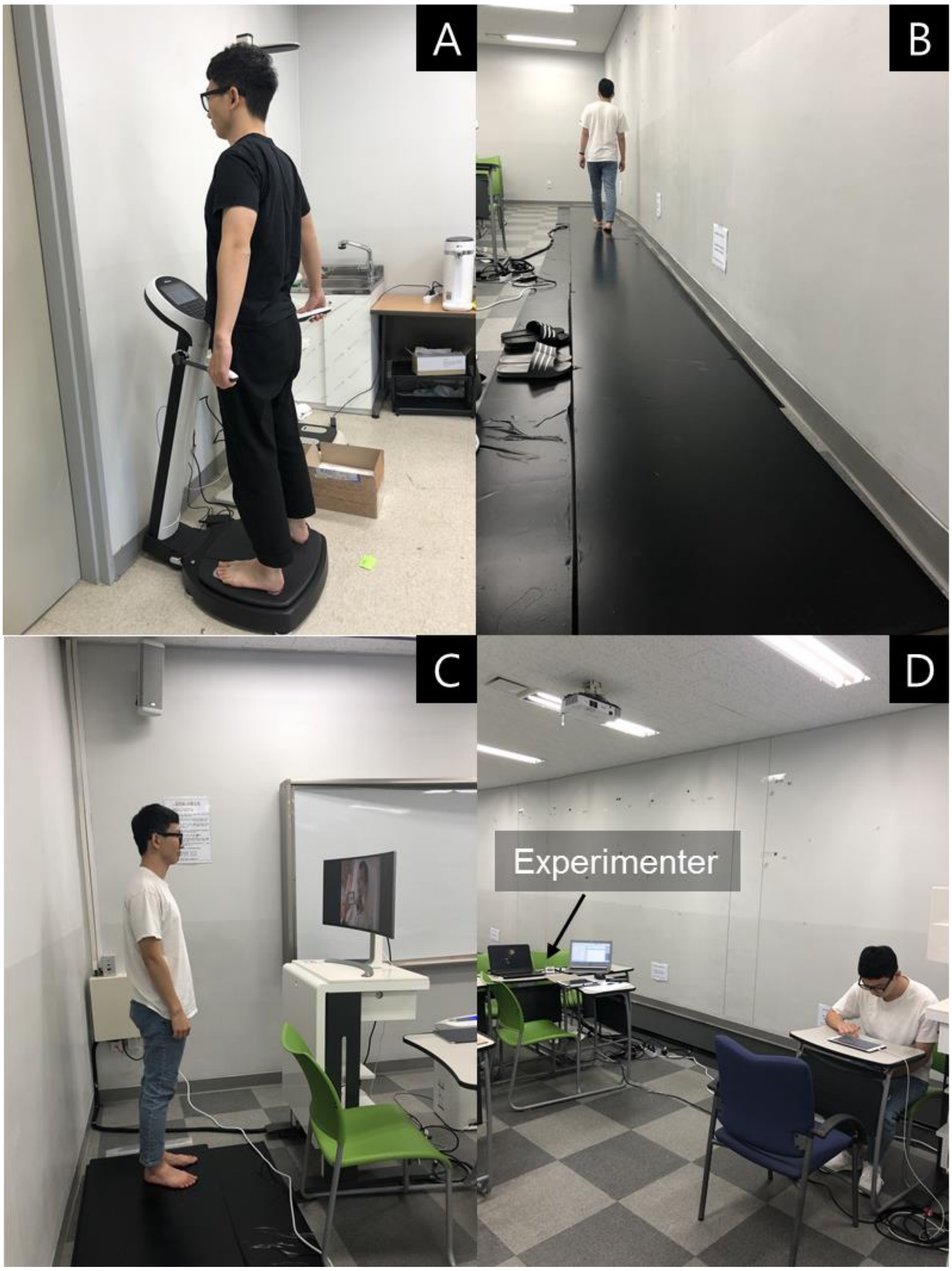


Figure 12. A: Measuring body composition using Inbody 570, B: Walking task on the walkway. C: Watching the video stimuli. D: Responding to the questionnaire.

Table 1. The Global Physical Activity Questionnaire (GPAQ).

Question		Response
Work		
P 1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like [carrying or lifting heavy loads, digging or construction work] for at least 10 minutes continuously?	Yes/No
P 2a	In a typical week, on how many days do you do vigorous intensity activities as part of your work?	Number of days
P 2b	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours : minutes
P 3	Does your work involve moderate-intensity activity, that causes small increases in breathing or heart rate such as brisk walking [or carrying light loads] for at least 10 minutes continuously?	Yes/No
P 4a	In a typical week, on how many days do you do moderate intensity activities as part of your work?	Number of days
P 4b	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours : minutes
Travel to and from places		
P 5	Do you walk or use a bicycle (pedal cycle) for at least 10 minutes continuously to get to and from places?	Yes/No
P 6a	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days
P 6b	How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes

Recreational activities

P 7	Do you do any vigorous-intensity sports, fitness or recreational (leisure) activities that cause large increases in breathing or heart rate like [running or football] for at least 10 minutes continuously?	Yes/No
P 8a	In a typical week, on how many days do you do vigorous intensity sports, fitness or recreational (leisure) activities?	Number of days
P 8b	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours : minutes
P 9	Do you do any moderate-intensity sports, fitness or recreational (leisure) activities that cause a small increase in breathing or heart rate such as brisk walking, [cycling, swimming, volleyball] for at least 10 minutes continuously?	Yes/No
P 10a	In a typical week, on how many days do you do moderate intensity sports, fitness or recreational (leisure) activities?	Number of days
P 10b	How much time do you spend doing moderate-intensity sports, fitness or recreational (leisure) activities on a typical day?	Hours : minutes

Sedentary behavior

P 11	How much time do you usually spend sitting or reclining on a typical day?	Hours : minutes

Table 2. Description of gait parameters.

Name			Abbreviation	Description
Spatiotemporal gait parameters	Maximum force	Forefoot (N)	M_F	The maximum force of forefoot during recording time.
		Rearfoot (N)	M_R	The maximum force of rearfoot during recording time.
	Geometry (G)	Foot Rotation (deg)	FR	The angle between the longitudinal axis of the foot and the walking direction.
		Step length (cm) *	STL	The distance between the heel contact of one side of the body and the heel contact of the contralateral side.
		Stride length (cm) *	SRL	The distance between the heel contact of one side of the body and the heel contact of the same side.
		Step width (cm) *	SW	The distance between the centers of the feet.
	Phases (P)	Stance phase (%)	ST	The phase of a gait cycle in which the foot has contact with the ground.
		Load response phase (%)	LR	The phase between the initial ground contact and contralateral toe off.
		Single support phase (%)	SS	The contralateral toe-off phase and the transfer of the body's center of gravity over the weight-bearing foot.
		Pre-swing phase (%)	PSW	The phase during a gait cycle that begins at contralateral initial contact (when the heel touches the ground) and ends at toe off of the viewed side of the body.
		Swing phase (%)	SW	The phase of a gait cycle during which the foot has no contact with the ground.
		Double stance phase (%) *	DS	Sum of the loading response phase and the pre-swing phase.
	Timing (T)	Step time (sec)	ST	The duration from the heel contact of one side to the heel contact of the contralateral side.
		Stride time (sec) *	SR	The duration from the heel contact of one side of the body to the heel contact of the same side.
		Cadence (steps/min) *	C	Step frequency
		Walking speed (km/h) *	V	Measured average gait speed during the analyzed measuring interval.
CoP butterfly parameters		Length of gait line (mm)	LoG	Average length of the butterfly diagram during stance phase of one side.
		Single support line (mm)	LoS	Average length of the butterfly diagram during single support phase of one side.

CoP butterfly parameters		AP position (mm) *	AP	Anteroposterior position of CoP intersection point.
		AP deviation (mm) *	AP_SD	The anteroposterior displacement of the CoP intersection point.
		Lateral symmetry (mm) *	ML	The medioleteral shift of the COP intersection point.
		ML deviation (mm)*	ML_SD	The medioleteral displacement of the CoP intersection point.
		Max. velocity (cm/sec) *	MV	The maximum velocity of butterfly diagram.
Force and pressure		Max. force 1 (N)	M1	First peak force of average gait cycle.
		Time to Max. force 1 (%)	TM1	Time to first peak force.
		Max. force 2 (N)	M2	Second peak force of average gait cycle.
		Time to Max. force 2 (%)	TM2	Time to second peak force.
Three-foot zone analysis	Load change	Time change heel to forefoot (sec, %)	LC	The absolute load change from the heel to the forefoot during the stance phase.
	Max. force (MF)	Forefoot (N)	F	The average maximum values reached in N for the three zones: toes, mid-foot and heel
		Midfoot (N)	M	
		Heel (N)	H	
	Max. pressure (MP)	Forefoot (N/cm^2)	F	The average maximum values reached in N/cm^2 for the three zones: toes, mid-foot and heel
		Midfoot (N/cm^2)	M	
		Heel (N/cm^2)	H	
	Time of M. force (T_MF)	Forefoot (%)	F	The average point in time within a gait cycle where the maximum value appears for the three zones toes, mid-foot and heel respectively
		Midfoot (%)	M	
		Heel (%)	H	
	Contact time (C)	Forefoot (%)	F	The average contact time of the three zones toes, mid-foot and heel.
		Midfoot (%)	M	
		Heel (%)	H	

Note. All variables except marked variables* were measured separately from the right (R) and left foot (L).

Note. The ‘Contact time of right forefoot’ was ‘C_F_R’.

2.4 Data analysis

The data were analyzed using Matlab R2019a (Mathworks Inc., Natick, USA) and Minitab 18 Statistical Software (Minitab Inc., PA, USA).

2.4.1 Association of emotional state with gait patterns

Association of emotional state with gait patterns was determined with emotional walking tasks. Since six participants were excluded due to software problems, the analysis was performed with forty-one participants (22 men and 19 women).

Pearson correlations were applied to examine the relationships between task, emotional response, and gait parameters, which normalized by weight and height to minimize the confounding effects (Hof, 1996) and maximize the effect of emotional state. The following formulas (Stansfield, Hillman, Hazlewood, & Robb, 2006) were used to normalize the gait parameters to dimensionless variables :

$$\mathrm{Normalized\ \ force} = \mathrm{force(N)} \div \left(\mathrm{mass(kg)} \cdot \mathrm{g(m/s^2)}\right)$$

$$\mathrm{Normalized\ \ time} = \mathrm{time(s)} \div \sqrt{\frac{\mathrm{height(m)}}{\mathrm{g\ \ (m/s^2)}}}$$

$$\mathrm{Normalizedcadence} = \mathrm{cadence(steps/min)} \div \left(\sqrt{\frac{\mathrm{g\ \ (m/s^2)}}{\mathrm{height(m)}}} \times \frac{60\mathrm{(s)}}{1\mathrm{(min)}}\right)$$

$$\mathrm{Normalizedlength} = \mathrm{length(cm)} \div \left(\mathrm{height(m)} \times \frac{100\mathrm{(cm)}}{1\mathrm{(m)}}\right)$$

$$\mathrm{Normalized\ \ velocity} = \mathrm{velocity(km/h)} \div \left(\sqrt{\frac{\mathrm{height(m)}}{\mathrm{g\ \ (m/s^2)}}} \times \frac{1\mathrm{(km)}}{1000\mathrm{(m)}} \times \frac{3600\mathrm{(s)}}{1\mathrm{(h)}}\right)$$

$$\mathrm{Gravitational\ \ acceleration\ \ (g)\ \ =\ \ 9.81m/s^2}$$

Statistical analysis was performed separately in men and women. The differences in emotional response between before and after tasks (joy, neutral, and sadness) were analyzed using the paired t-test. To examine the effect emotion on emotional response, a general linear model with Tukey post-hoc analyses was used. In the model, V_{before} and A_{before}were considered as a covariate because they would affect emotional response after the task. The fixed effect was the emotion and the random effect was the participant.

Before analyzing the effect of emotional walking on gait patterns, a paired t-test was performed to analyze the differences between the left and right foot. Because the result showed no significant difference, the walking parameters were averaged by both sides. In order to avoid potential multicollinearity problems, the representative gait parameters which were correlated with task and V_{after} were chosen based on the result of Pearson correlation matrix. Finally, thirteen gait parameters (G_STL, P_ST, P_SW, P_DS, T_ST, T_C, T_V, LoS, AP_SD, ML_SD, M1, TM1, M2) were selected.

Repeated measured analysis of variance (ANOVA) with Tukey post-hoc analyses were performed to examine effect of emotion on the gait parameters. The fixed effect was the emotion and the random effect was the participant. The effect size (η^2) was calculated using the following formula. The effect size was interpreted along the guidelines proposed by (Cohen, 2013): 0.01 = small effect size, 0.06 = medium effect size and 0.14 = large effect size.

$$\eta^2 = \frac{SS_{task}}{SS_{total}}$$

2.4.2 Association of body composition with gait patterns

Two participants were excluded in the analysis of the association of body composition with gait patterns; one was due to software problems, and another was an outlier of body composition. Thus, forty-five participants (23 men and 22 women) were included in the analysis. The intensity of physical activity, which was measured by the GPAQ, was categorized into five using the following equations. The METs (Metabolic Equivalents), which express the intensity of physical activities, were used for the analysis of the GPAQ (WHO, 2012). Since all participants were university students, no one was involved in vigorous work, and only two of them were involved in moderate work. Thus, these two variables were excluded from the statistical analysis.

$$\text{Vigorous work (V work) (mins/week)} = \text{P2a} \times \text{P2b}$$

$$\text{Moderate work (M work) (mins/week)} = \text{P4a} \times \text{P4b}$$

$$\text{Vigorous recreational activities (V rec) (mins/week)} = \text{P8a} \times \text{P8b}$$

$$\text{Moderate recreational activities (M rec) (mins/week)} = \text{P10a} \times \text{P10b}$$

$$\text{Total MET (mins/week)} = 8 \times (\text{V work}) + 4 \times (\text{M work}) + 8 \times (\text{V rec}) + 4 \times (\text{M rec})$$

Statistical analysis was performed separately in men and women. Pearson correlations were performed to establish the relationship between the intensity of physical activity, body composition, and gait patterns. To reduce multicollinearity, the representative gait parameters were selected based on Pearson correlation matrix, which was on the only right side (G_SRL, T_SR, T_C, T_V, AP_SD, ML_SD, LoG_R, LoS_R, MF_F_R, MF_M_R, MF_H_R, C_F_R, C_M_R, C_H_R). The data were then randomly divided into two groups. One was a prediction group (19 men and 18 women), which was used for regression analysis, and another was a validation group (5 men and 4 women) for validating the model. Multiple linear regression analyses were performed on the prediction group to determine the best model to predict body composition. The forward-stepwise selection procedure was used to select predictors. The significance for all statistical analyses was set at $\alpha=0.05$.

3. RESULT

3.1 Emotional response

3.1.1 Intensity of valence

The paired t-test indicated that the intensity of valence decreased after sadness task (men: t(22)=7.04, $p<0.001$; women: t(19)=7.63, $p<0.001$), and increased after joy task (men: t(22)=-6.86, $p<0.001$; women: t(19)=-7.89, $p<0.001$), and there was no significant difference between before and after neutral task for both women and men participants (men: t(22)=0.36, p=0.724; women: t(19)=-1.02, p=0.320). The intensity of valence after the three tasks increased in the order of sadness, neutral, and joy. The men showed a significant difference between sadness (M= 3.773, SD=1.232), neutral (M=6.000, SD=1.024) and joy (M=7.318, SD=0.995) ($p<0.001$), but the women showed a significant difference in sadness (M=2.842, SD=1.675) and neutral (M= 6.263, SD=1.695), and sadness and joy (M=7.053, SD=1.129) ($p<0.001$).

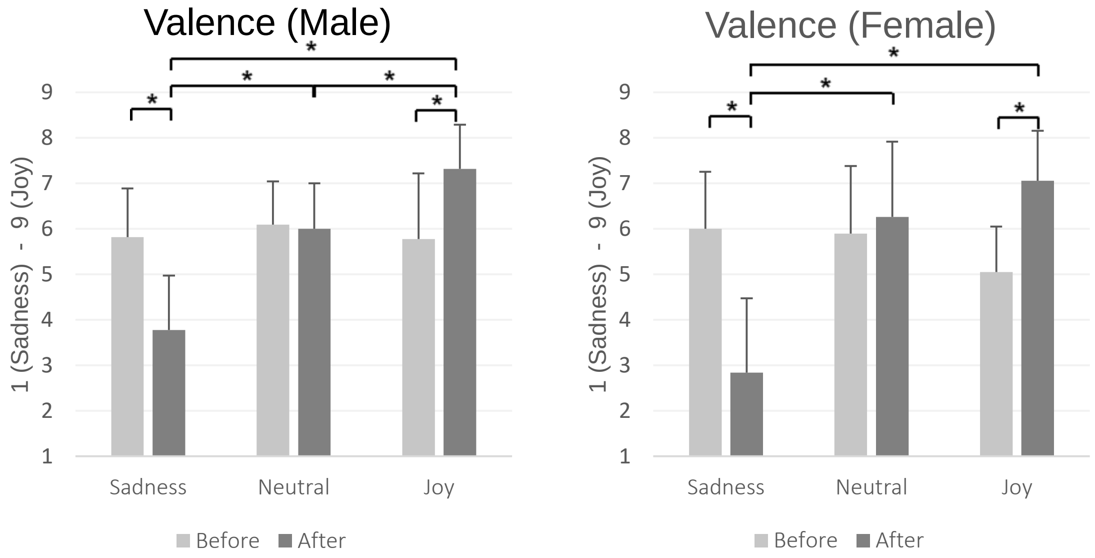


Figure 13. Emotional response (Valence) of men (left) and women (right).
(* means that they are significantly different.)

3.1.2 Intensity of arousal

The intensity of arousal decreased after neutral task (men: t(22)=-2.91, p<0.001; women: t(19)=6.51, p<0.001) and joy task (men: t(22)=-5.28, p<0.001; women: t(19)=-5.51, p<0.001), and there was no significant difference between before and after sadness task for both women and men participants (men: t(22)=0.98, p=0.336; women: t(19)=0.49, p=0.630). The intensity of arousal was the lowest after the neutral task and increased in the order of sadness and joy. For men, there was a significant difference between sadness (M= 2.682, SD=1.985) and joy (M=4.364, SD=1.002), and neutral (M=2.227, SD=1.378) and joy (p<0.001). For women, there was a significant difference in sadness (M=3.316, SD=2.136), neutral (M= 1.737, SD=0.991) and joy (M=5.000, SD=1.915) (p<0.001).

Figure 14. Emotional response of men.
(* means that they are significantly different.)

3.2 Association of emotional state with gait patterns

3.2.1 Men

As shown in Table 3, for men, the result showed that spatiotemporal gait parameters significantly differ among the emotions. Normalized step length increased in the order of sadness, neutral, and joy ($p<0.05$). Normalized step time significantly decreased, and cadence and walking speed increased in joy and neutral than sadness (all $p<0.05$). In a whole gait cycle (100%), the percentage of stance phase and double support phase were shorter, and the swing phase was longer for joy than sad (all $p<0.05$). Regarding the center of pressure variables, the normalized length of the CoP path during the single support phase was longer and normalized mediolateral displacement of the CoP intersection point was smaller in joy than sadness (all $p<0.05$). There was no significant change in normalized anteroposterior displacement of the CoP intersection point. Among force parameters, normalized the 1st peak force and the 2nd peak force significantly increased, and time to the 1st peak force significantly became shorter in joy than sadness (all $p<0.05$).

Effect size, eta squared, was calculated using the result from statistical analysis. For men, normalized time variables including step time, cadence, and walking speed had large effect size (all $\eta^2>0.14$). Normalized step length, gait phase variables such as stance, swing and double support phases, normalized mediolateral displacement of CoP intersection point, time to the 1st peak, and the 2nd peak force had medium effect size (all $\eta^2>0.06$). The normalized length of CoP path during single support phase and the 1st peak force had small effect size ($\eta^2=0.04$ and $\eta^2=0.05$, respectively).

3.2.2 Women

In Table 4, for women, normalized step length, cadence, and walking speed increased, and step time decreased in the order of sadness, neutral, and joy ($p<0.05$). The change of gait phase also significantly differed in three emotions. In order of sadness, neutral and joy, the percentage of stance phase and double support phase became shorter, and the swing phase became longer of the whole gait cycle. Among CoP variables, only the normalized length of the CoP path during the single support phase has significantly differed between emotions ($p<0.05$). When feeling neutral and joy, the length was longer than feeling sadness. Displacement of CoP did not show a significant difference between emotion. Time to the 1st peak force was significantly different between three emotions, and the time decreased in the order of sadness, neutral, and joy ($p<0.05$). The 1st peak force and the 2nd peak force were higher in joy than sadness (all $p<0.05$).

Compared to the result of men, for women, most of the gait parameters, including normalized step length, all gait phase variables, all time variables, the 1st peak, and time to the 1st peak had large effect size (all $\eta^2>0.14$). The normalized length of the CoP path during single support phase and the

2nd peak force had medium effect size (η^2=0.10 and η^2=0.11, respectively).

Table 3. Result of ANOVA with Tukey post-hoc analysis (Men), mean (standard deviation).

Gait	Emotion			Statistics		Effect Size
parameters	Sadness	Neutral	Joy	F-value	P-value	η2
G_STL	0.309 (0.029)	0.32 (0.029)	0.333 (0.026)	18.97	<0.001	0.12
	(A)	(B)	(C)			
P_ST	65.573 (1.646)	65.153 (1.305)	64.52 (1.43)	7.29	0.002	0.08
	(A)	(AB)	(B)			
P_SW	34.427 (1.646)	34.847 (1.305)	35.48 (1.43)	7.29	0.002	0.08
	(A)	(AB)	(B)			
P_DS	31.348 (3.191)	30.668 (2.637)	28.887 (2.845)	9.93	<0.001	0.11
	(A)	(A)	(B)			
T_ST	1.507 (0.173)	1.47 (0.163)	1.341 (0.109)	26.02	<0.001	0.18
	(A)	(A)	(B)			
T_C	0.673 (0.072)	0.69 (0.07)	0.749 (0.054)	30.46	<0.001	0.19
	(A)	(A)	(B)			
T_V	0.209 (0.033)	0.222 (0.036)	0.25 (0.029)	29.96	<0.001	0.22
	(A)	(A)	(B)			
LoS	0.064 (0.005)	0.064 (0.005)	0.066 (0.005)	5.64	0.007	0.04
	(A)	(AB)	(B)			
AP_SD	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)	1.48	0.24	0.04
	(A)	(A)	(A)			
ML_SD	0.003 (0.001)	0.002 (0.001)	0.002 (0.001)	4.62	0.015	0.09
	(A)	(AB)	(B)			
M1	1.084 (0.036)	1.094 (0.032)	1.112 (0.068)	3.61	0.036	0.05
	(A)	(AB)	(B)			
TM1	18.568 (2.303)	17.705 (2.071)	16.75 (2.125)	11.5	<0.001	0.10
	(A)	(A)	(B)			
M2	1.106 (0.026)	1.112 (0.028)	1.133 (0.035)	16.08	<0.001	0.13
	(A)	(A)	(B)			

Note. All variables were normalized by height and weight. G_STL: Step length; P_ST: Stance phase; P_SW: Swing phase; P_DS: Double support phase T_ST: Step time; T_C: Cadence; T_V: Walking speed; LoS: Length of the butterfly diagram during stance phase and during single support phase; AP_SD and ML_SD: Anteroposterior and mediolateral displacement of CoP intersection point; M1 and M2: the 1st and the 2nd peak force of average gait cycle; TM1: Time to the 1st peak force.

Table 4. Result of ANOVA with Tukey post-hoc analysis (Women), mean (standard deviation).

Gait parameters	Emotion			Statistics		Effect Size η2
	Sadness	Neutral	Joy	F-value	P-value	
G_STL	0.297 (0.049) (A)	0.321 (0.032) (B)	0.35 (0.035) (C)	20.16	<0.001	0.23
P_ST	68.045 (3.852) (A)	66.367 (2.269) (B)	64.387 (1.858) (C)	18.68	<0.001	0.22
P_SW	31.955 (3.852) (A)	33.634 (2.269) (B)	35.613 (1.858) (C)	18.68	<0.001	0.22
P_DS	36.281 (7.856) (A)	33.178 (4.76) (B)	28.776 (3.739) (C)	19.94	<0.001	0.22
T_ST	1.861 (0.483) (A)	1.681 (0.291) (B)	1.368 (0.129) (C)	22.97	<0.001	0.27
T_C	0.571 (0.126) (A)	0.614 (0.096) (B)	0.738 (0.065) (B)	44.03	<0.001	0.34
T_V	0.174 (0.059) (A)	0.199 (0.046) (B)	0.259 (0.04) (C)	48.81	<0.001	0.34
LoS	0.055 (0.015) (A)	0.062 (0.007) (B)	0.063 (0.007) (B)	6.47	0.004	0.10
AP_SD	0.003 (0.002) (A)	0.002 (0.001) (A)	0.002 (0.001) (A)	1.94	0.159	0.07
ML_SD	0.004 (0.003) (A)	0.003 (0.001) (A)	0.002 (0.001) (A)	1.93	0.16	0.06
M1	1.104 (0.02) (A)	1.097 (0.021) (A)	1.13 (0.048) (B)	6.08	0.005	0.16
TM1	21.5 (3.924) (A)	19.605 (2.447) (B)	17.947 (2.449) (C)	16.62	<0.001	0.19
M2	1.108 (0.032) (A)	1.119 (0.027) (A)	1.138 (0.043) (B)	13.08	<0.001	0.11

Note. All variables were normalized by height and weight. G_STL: Step length; P_ST: Stance phase; P_SW: Swing phase; P_DS: Double support phase T_ST: Step time; T_C: Cadence; T_V: Walking speed; LoS: Length of the butterfly diagram during stance phase and during single support phase; AP_SD and ML_SD: Anteroposterior and mediolateral displacement of CoP intersection point; M1 and M2: the 1st and the 2nd peak force of average gait cycle; TM1: Time to the 1st peak force.

3.3 Correlation between the intensity of physical activity and body composition and gait parameters

Table 5 showed information about the intensity of physical activity. Men showed spent more time on vigorous recreational activities and total physical activity than women. Women spent more time to travel to and from the place and sedentary behavior.

Only a few variables were correlated between the intensity of physical activity and gait parameters in men. Total physical activity was correlated with stride time (r=-0.58, p<0.01), cadence (r=0.61, p<0.01) and mediolateral displacement of CoP intersection point (r=0.49, p=0.03). Moderate recreational activity was correlated with mediolateral displacement of CoP intersection point (r=0.48, p=0.02). There was no correlation between physical activity and body composition.

In women, there was no correlation between the intensity of physical activity and gait parameters. Only time to sedentary behavior correlated with body composition, total fat mass (r=-0.45, p=0.03), right arm fat mass (r=-0.51, p=0.02), trunk fat mass (r=-0.46, p=0.03), and right leg fat mass (r=-0.43, p=0.05).

Table 5. The information of intensity of physical activity (M: mean; SD: standard deviation)

	Men		Women	
	M	SD	M	SD
Travel (min/week)	280.0	129.0	343.0	161.3
Vigorous rec (min/week)	174.3	240.5	74.5	112.6
Moderate rec. (min/week)	106.5	162.1	106.1	150.0
Sedentary (min/week)	554.3	198.4	640.9	150.7
Total Physical Activity MET (min/week)	3050.4	2116.5	2501.8	1204.5

3.4 Correlation between gait parameters

3.4.1 Men

In the Table 6, the correlation matrix was described for men. Between gait parameters, stride length had positive correlation with walking speed (r=0.85, p<0.01) and length of CoP path during stance phase (r=0.65, p<0.01) and single support phase (r=0.61, p<0.01) and negative correlation with anteroposterior (r=-0.53, p=0.01) and mediolateral (r=-0.57, p<0.01) displacement of CoP intersection point and maximum force (r=-0.46, p=0.03) and contact time (r=-0.71, p<0.01) of right midfoot.

Time variables was intercorrelated. Stride time was negatively correlated with cadence (r=-0.99, p<0.01) and walking speed (r=-0.51, p=0.01) which were correlated with each other (r=0.47, p=0.02). Walking speed was positively correlated with stride length (r=0.85, p<0.01) and length of CoP path during single support phase (r=0.53, p=0.01) and negatively correlated with step time (r=-0.51, p=0.01), anteroposterior displacement of CoP intersection point (r=-0.44, p=0.04), and maximum force (r=-0.48, p=0.02) and contact time of right midfoot (r=-0.55, p=0.01).

Among CoP variables, anteroposterior displacement of the CoP intersection point was positively correlated with the mediolateral displacement of the CoP intersection point (r=0.61, p<0.01), and it was negatively correlated with length of CoP path during stance phase (r=-0.58, p<0.01). Length of CoP path during single support phase which was positively correlated with length of CoP path during stance phase (r=0.56, p=0.01) have positive correlation with stride length (r=0.61, p<0.01) and walking speed (r=0.53, p=0.01) and negative correlation with contact time of right forefoot (r=-0.42, p=0.05) and right midfoot (r=-0.56, p=0.01). Length of CoP path during stance phase was also positively correlated with stride length (r=0.65, p<0.01) and negatively correlated with contact time of right forefoot (r=-0.48, p=0.02) and right midfoot (r=-0.53, p=0.01), but, contrary to length during single support phase, it was not correlated with walking speed, and it was positively correlated with maximum force of right heel (r=0.44, p=0.03).

In the three-foot analysis, the maximum force of the right forefoot and right heel only showed positive intercorrelation (r=0.74, p<0.01), and others not correlated with each other. Contact time of right forefoot was positively correlated with the contact time of right midfoot (r=0.50, p=0.02) and negatively correlated with the contact time of the right heel (r=-0.66, p<0.01). Between plantar force and contact time, there were positive correlations that the maximum force of right forefoot and right heel were correlated with the contact time of right forefoot and right heel, respectively (r=0.62, p=0.02; r=0.43, p<0.01).

3.4.2 Women

In Table 7, the correlation was described for women. Women has smaller significant correlations between gait parameters than men. The stride length was positively correlated with walking speed (r=0.68, p<0.01), length of the CoP path during the stance phase (r=0.45, p=0.03), and maximum force of right forefoot (r=0.59, p<0.01).

There was a strong correlation between time variables (all |r|>0.80, all p<0.01). Step time and cadence were not correlated with other gait parameters. Walking speed was correlated with stride length (r=0.68, p<0.01) and maximum force of right forefoot (r=0.59, p<0.01).

Regarding CoP parameters, anteroposterior displacement of CoP intersection point and mediolateral displacement of CoP intersection point had a positive correlation (r=0.64, p<0.01) and length of CoP path during stance phase and length of CoP path during single support phase also had a positive correlation (r=0.48, p=0.02). The length of the CoP path during the stance phase was positively correlated with the maximum force of right heel (r=0.49, p=0.02) and negatively correlated with the contact time of right midfoot (r=-0.43, p=0.04). The length of the CoP path during single support phase was negatively correlated with the maximum force of right midfoot (r=-0.58, p=0.01) and contact time of right forefoot (r=-0.43, p=0.05).

In the three-foot analysis, only two intercorrelations were found. The maximum force of right forefoot and right heel showed positive intercorrelation (r=0.70, p<0.01), and contact time of right forefoot was positively correlated with the contact time of right midfoot (r=0.43, p=0.04). Between plantar force and contact time, there were positive correlations that the maximum force of right forefoot and right midfoot were correlated with the contact time of right forefoot and right midfoot, respectively (r=0.64, p<0.01; r=0.60, p<0.01).

3.5 Correlation between body composition

3.5.1 Men

Height was positively correlated with total fat-free mass except for right arm fat-free mass (all $r>0.44$, all $p<0.05$) and weight was correlated with all segmental fat mass (all $r>0.75$, all $p<0.01$) and all segmental fat-free mass (all $r>0.45$, all $p<0.05$). Total fat-free mass and total fat mass were respectively intercorrelated with those of each segment (all $r>0.6$, all $p<0.01$; all $r>0.9$, all $p<0.01$). BMI had negative correlation with height ($r=-0.42$, $p=0.04$) and positive correlation with weight ($r=0.85$, $p<0.01$) and total fat mass including all segmental fat mass (all $r>0.8$, all $p<0.01$). Between BMI and total fat-free mass, including the fat-free mass of each segment, there was no correlation (Table 6).

3.5.2 Women

The correlation between body composition was very similar to men results. However, contrary to men, for women, the height was positively correlated with weight ($r=0.50$, $p=0.02$) and right arm fat-free mass ($r=0.55$, $p=0.01$) and there was no correlation between height and BMI (Table 7).

3.6 Correlation between body composition and gait parameters

3.6.1 Men

In Table 6, height was correlated with most of the gait parameters. Walking speed and mediolateral displacement of the CoP intersection point were moderately correlated, and others were strongly correlated with height. The height was positively correlated with stride length ($r=0.5$, $p=0.02$), walking speed ($r= 0.49$, $p=0.02$), length of CoP path during stance phase ($r=0.60$, $p<0.01$) and during single support ($r= 0.58$, $p<0.01$) and maximum force of right heel ($r=0.56$, $p=0.01$). It was negatively correlated with anteroposterior ($r=-0.53$, $p=0.01$) and mediolateral ($r=-0.43$, $p=0.04$) displacement of CoP intersection point and contact time of right midfoot ($r=-0.59$, $p<0.01$). The weight had a positively strong correlation with the maximum force of right forefoot and right heel (all $r>0.7$, all $p<0.01$) and positively moderate correlation with the maximum force of right midfoot ($r=0.59$, $p<0.01$). BMI had positively week correlation with contact time of right midfoot ($r=0.49$, $p=0.02$) and moderate correlation maximum force of right forefoot ($r=0.59$, $p<0.01$) and right midfoot ($r=0.67$, $p<0.01$).

Total fat mass had a moderate positive correlation with the maximum force of right forefoot and midfoot (all $r>0.5$, $p<0.05$), and it had a weak positive correlation with the maximum force of right heel ($r=0.44$, $p=0.04$). The segmental fat mass showed a similar correlation with the maximum plantar force. Only right arm fat mass was not correlated with the maximum force of the right heel. Total fat-free mass had a moderate positive correlation with length of CoP path during the stance phase ($r=0.45$, $p=0.03$) and strong correlation with the maximum force of right forefoot and heel (all $r>0.7$, all $p<0.01$). Segmental fat-free mass also had a similar relationship with gait parameters. Among segmental fat-free mass variables, trunk and right leg had a strong correlation with the maximum force of right forefoot and right heel, respectively ($r=0.71$, $p<0.01$; $r=0.73$, $p<0.01$). Additionally, trunk fat-free mass had a positive moderate correlation with length of CoP path during stance phase, and right leg fat-free mass had a strong correlation with length of CoP path during stance phase ($r=0.59$, $p<0.01$) and weak correlation with length of CoP path during single support phase ($r=0.49$, $p=0.02$).

3.6.2 Women

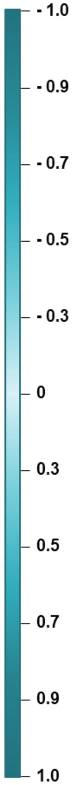
In Table 7, height had positively moderate correlation length of CoP path during stance phase ($r=0.64$, $p<0.01$) and maximum force of right heel ($r=0.56$, $p=0.01$), and positively weak correlation with maximum force of right forefoot ($r=0.48$, $p=0.02$), but it had negatively moderate correlation with mediolateral displacement of CoP intersection point ($r=-0.44$, $p=0.04$). Weight had positively strong correlation with maximum force of right forefoot ($r=0.89$, $p<0.01$) and positively moderate correlation with right heel ($r=0.64$, $p<0.01$) and contact time of right forefoot ($r=0.58$, $p<0.01$) and right midfoot ($r=0.57$, $p<0.01$). BMI had a weak positive correlation with cadence ($r=0.45$, $p=0.04$) and moderate correlation with maximum force and contact time of right forefoot and right midfoot (all $r>0.5$, all

$p<0.05$), and it had negatively moderate correlation with length of CoP path during single support phase ($r=-0.56$, $p=0.01$).

Total fat mass had a moderate positive correlation with the maximum force of right forefoot and contact time of forefoot and midfoot (all $r>0.5$, $p<0.05$), and it had a weak negative correlation with length of CoP path during single support phase ($r=-0.46$, $p=0.03$). These correlations were also presented in segmental fat mass. Only right leg fat mass was not correlated with the length of the CoP path during the single support phase. Additionally, trunk fat mass had a moderate positive correlation with the maximum force of right midfoot ($r=0.44$, $p=0.04$). Total fat-free mass had a moderate positive correlation with the maximum force of right forefoot and heel (all $r>0.5$, all $p<0.01$). Segmental fat-free mass also had a moderate positive correlation with the maximum force of right forefoot and heel (all $r>0.5$, all $p<0.01$).

Table 6. The correlation coefficient (R-value) between body composition and gait parameters (Men). The uncolored result presented an insignificant correlation between variables. The significant correlation was colored depending on the R-value. Darker color means that the two variables were highly correlated.

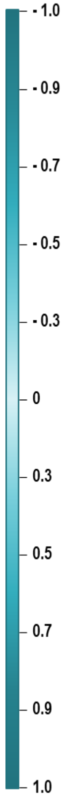
		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.
1.	G_SRL	1.00																								
2.	T_SR	0.00	1.00																							
3.	T_C	-0.06	-0.99	1.00																						
4.	T_V	0.85	-0.51	0.47	1.00																					
5.	AP_SD	-0.53	0.02	0.05	-0.44	1.00																				
6.	ML_SD	-0.57	-0.24	0.31	-0.34	0.61	1.00																			
7.	LoG_R	0.65	0.32	-0.36	0.41	-0.58	-0.49	1.00																		
8.	LoS_R	0.61	0.04	-0.03	0.53	-0.35	-0.16	0.56	1.00																	
9.	MF_F_R	0.36	0.00	-0.01	0.30	-0.50	-0.22	0.33	0.16	1.00																
10.	MF_M_R	-0.46	0.23	-0.17	-0.48	0.11	0.22	0.06	-0.30	0.18	1.00															
11.	MF_H_R	0.28	0.05	-0.05	0.23	-0.49	-0.27	0.44	0.39	0.74	0.10	1.00														
12.	C_F_R	-0.30	-0.40	0.45	-0.05	0.36	0.44	-0.48	-0.42	0.09	0.26	-0.30	1.00													
13.	C_M_R	-0.71	-0.13	0.17	-0.55	0.30	0.40	-0.53	-0.56	-0.15	0.62	-0.26	0.50	1.00												
14.	C_H_R	-0.11	0.03	-0.04	-0.10	-0.31	-0.04	0.11	0.39	-0.10	-0.10	0.43	-0.66	-0.07	1.00											
15.	Height	0.50	-0.06	0.06	0.49	-0.53	-0.43	0.60	0.58	0.29	-0.27	0.56	-0.26	-0.59	0.17	1.00										
16.	Weight	-0.07	0.18	-0.15	-0.15	-0.28	-0.06	0.18	-0.01	0.82	0.59	0.71	0.14	0.20	0.01	0.11	1.00									
17.	BFM	-0.32	0.20	-0.19	-0.39	-0.12	-0.06	-0.09	-0.27	0.55	0.65	0.44	0.08	0.40	0.10	-0.27	0.84	1.00								
18.	FFM	0.29	0.06	-0.04	0.23	-0.35	-0.03	0.45	0.34	0.77	0.22	0.73	0.15	-0.16	-0.11	0.55	0.72	0.24	1.00							
19.	BMI	-0.33	0.17	-0.15	-0.38	0.03	0.19	-0.16	-0.32	0.59	0.67	0.36	0.28	0.49	-0.09	-0.42	0.85	0.91	0.37	1.00						
20.	FFM RA	0.27	0.13	-0.11	0.18	-0.12	0.12	0.37	0.21	0.68	0.16	0.54	0.24	-0.15	-0.31	0.36	0.60	0.13	0.91	0.36	1.00					
21.	FFM TR	0.30	0.06	-0.04	0.24	-0.20	0.07	0.41	0.27	0.71	0.16	0.61	0.20	-0.19	-0.25	0.45	0.63	0.15	0.94	0.34	0.99	1.00				
22.	FFM RL	0.46	-0.09	0.10	0.47	-0.56	-0.32	0.59	0.49	0.60	0.03	0.73	-0.02	-0.35	0.05	0.86	0.48	0.02	0.84	-0.01	0.63	0.71	1.00			
23.	BFM RA	-0.33	0.12	-0.11	-0.34	-0.11	-0.10	-0.15	-0.26	0.48	0.63	0.41	0.05	0.39	0.13	-0.25	0.78	0.98	0.15	0.84	0.01	0.04	0.00	1.00		
24.	BFM TR	-0.31	0.23	-0.21	-0.39	-0.11	-0.04	-0.08	-0.27	0.57	0.66	0.44	0.10	0.40	0.07	-0.28	0.86	1.00	0.27	0.93	0.19	0.20	0.02	0.97	1.00	
25.	BFM RL	-0.32	0.17	-0.16	-0.37	-0.17	-0.11	-0.09	-0.25	0.50	0.64	0.44	0.03	0.40	0.17	-0.24	0.80	0.99	0.18	0.85	0.03	0.06	0.02	0.99	0.98	1.00



Note. G_SRL_R: Stride length; T_SR: Stride time; T_C: Cadence; T_V: Walking speed; AP_SD and ML_SD: Anteroposterior and mediolateral displacement of CoP intersection point; LoG_R and LoS_R: Right length of the butterfly diagram during stance phase and during single support phase; MF_F_R, MF_M_R and MF_H_R: Maximum force of right forefoot, midfoot and heel; C_F_R, C_M_R and C_H_R: Contact time of right forefoot, midfoot and heel; BFM: Total fat mass; FFM: Total fat-free mass; BMI: Body mass index; RA: Right arm; TR: Trunk; RL: Right leg.

Table 7. The correlation coefficient (R-value) between body composition and gait parameters (Women). The uncolored result presented an insignificant correlation between variables. The significant correlation was colored depending on the R-value. Darker color means that the two variables were highly correlated.

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.
1.	G_SRL	1.00																								
2.	T_SR	-0.20	1.00																							
3.	T_C	0.19	-0.99	1.00																						
4.	T_V	0.68	-0.84	0.84	1.00																					
5.	AP_SD	-0.21	0.18	-0.18	-0.25	1.00																				
6.	ML_SD	-0.34	0.22	-0.17	-0.31	0.64	1.00																			
7.	LoG_R	0.45	0.36	-0.40	-0.04	-0.04	-0.14	1.00																		
8.	LoS_R	0.23	0.04	-0.05	0.10	0.23	0.17	0.48	1.00																	
9.	MF_F_R	0.59	-0.36	0.36	0.59	-0.31	-0.39	0.29	-0.09	1.00																
10.	MF_M_R	-0.29	0.11	-0.08	-0.22	-0.08	0.08	-0.29	-0.58	0.14	1.00															
11.	MF_H_R	0.36	-0.18	0.14	0.30	-0.25	-0.34	0.49	0.21	0.70	-0.03	1.00														
12.	C_F_R	0.31	-0.16	0.20	0.33	-0.35	-0.23	-0.10	-0.43	0.64	0.28	0.11	1.00													
13.	C_M_R	-0.08	-0.25	0.30	0.19	-0.21	-0.10	-0.43	-0.42	0.37	0.60	0.21	0.43	1.00												
14.	C_H_R	-0.28	0.23	-0.19	-0.28	-0.10	0.10	-0.15	0.11	0.00	0.06	0.06	0.02	0.41	1.00											
15.	Height	0.36	0.16	-0.21	0.05	-0.11	-0.44	0.64	0.30	0.48	-0.29	0.55	0.26	0.01	0.14	1.00										
16.	Weight	0.38	-0.24	0.25	0.40	-0.28	-0.35	0.16	-0.28	0.89	0.38	0.64	0.66	0.57	-0.01	0.50	1.00									
17.	BFM	0.39	-0.22	0.26	0.41	-0.30	-0.27	-0.11	-0.46	0.63	0.41	0.32	0.58	0.52	-0.12	-0.03	0.69	1.00								
18.	FFM	0.14	-0.11	0.08	0.15	-0.08	-0.21	0.32	0.07	0.60	0.11	0.57	0.34	0.27	0.10	0.72	0.70	-0.04	1.00							
19.	BMI	0.14	-0.40	0.45	0.41	-0.22	-0.06	-0.32	-0.56	0.63	0.65	0.30	0.55	0.67	-0.11	-0.20	0.75	0.79	0.25	1.00						
20.	FFM RA	0.19	-0.15	0.14	0.21	-0.01	-0.10	0.24	0.03	0.63	0.16	0.54	0.32	0.30	0.04	0.55	0.70	0.02	0.95	0.37	1.00					
21.	FFM TR	0.21	-0.13	0.12	0.21	-0.06	-0.16	0.30	0.04	0.67	0.15	0.58	0.38	0.30	0.07	0.63	0.74	0.05	0.97	0.36	0.99	1.00				
22.	FFM RL	0.19	-0.07	0.04	0.15	-0.11	-0.32	0.42	0.18	0.59	0.01	0.61	0.35	0.26	0.16	0.86	0.69	0.01	0.93	0.12	0.80	0.86	1.00			
23.	BFM RA	0.37	-0.22	0.25	0.39	-0.34	-0.32	-0.11	-0.47	0.56	0.42	0.25	0.54	0.50	-0.15	-0.05	0.62	0.98	-0.12	0.73	-0.09	-0.05	-0.05	1.00		
24.	BFM TR	0.39	-0.22	0.25	0.40	-0.28	-0.24	-0.11	-0.50	0.66	0.44	0.31	0.59	0.52	-0.13	-0.04	0.72	0.99	0.01	0.83	0.10	0.12	0.02	0.96	1.00	
25.	BFM RL	0.36	-0.24	0.27	0.41	-0.33	-0.33	-0.08	-0.38	0.58	0.36	0.33	0.55	0.50	-0.08	0.04	0.65	0.97	-0.06	0.70	-0.06	-0.01	0.07	0.96	0.92	1.00



Note. G_SRL_R: Stride length; T_SR: Stride time; T_C: Cadence; T_V: Walking speed; AP_SD and ML_SD: Anteroposterior and mediolateral displacement of CoP intersection point; LoG_R and LoS_R: Right length of the butterfly diagram during stance phase and during single support phase; MF_F_R, MF_M_R and MF_H_R: Maximum force of right forefoot, midfoot and heel; C_F_R, C_M_R and C_H_R: Contact time of right forefoot, midfoot and heel; BFM: Total fat mass; FFM: Total fat-free mass; BMI: Body mass index; RA: Right arm; TR: Trunk; RL: Right leg.

3.7 Multiple regression prediction model

3.7.1 Men

The multiple regression for men was calculated to predict body composition based on their gait parameters, which were only measured on the right side. All model was significant (all $p<0.05$), as shown in Table 8.

Length of CoP path during right single support phase, the maximum force of right forefoot and right heel, and contact time of right midfoot explained 68% of the accounted variability of height (F(4, 13) = 6.80, p=0.004) and R^2 obtained for the validation group was 52%. The maximum force of the right heel significantly increased the height. (β=0.0617, $p<0.01$).

Walking speed and maximum force of right forefoot, midfoot and right heel explained 94% of the accounted variability of weight (F(4, 13) = 46.88, $p<0.001$) and R^2 obtained for the validation group was 97%. Walking speed significantly decreased the weight (β=-4.12, $p<0.05$) and maximum force of right forefoot and the right midfoot significantly increased the weight (β=0.0649, $p<0.001$; β=0.03488, $p<0.01$).

Cadence, length of CoP path during right stance phase and maximum force of right forefoot and right midfoot explained 84% of the accounted variability of BMI (F(4, 13) = 17.67, $p<0.001$) and R^2 obtained for the validation group was 98%. Cadence and length of CoP path significantly decreased BMI (β=-0.1089, $p<0.05$; β=-0.1029, $p<0.01$) and maximum force of right forefoot and right midfoot significantly increased BMI (β=0.01907, $p<0.001$; β=0.01635, $p<0.01$).

Walking speed, mediolateral displacement of CoP intersection point, length of CoP path during right stance phase and maximum force of right forefoot and right midfoot explained 87% of the accounted variability of total fat mass (F(5, 12) = 15.57, $p<0.001$) and R^2 obtained for the validation group was 77%. Mediolateral displacement and the length of CoP path significantly decreased total fat mass (β=-0.909, $p<0.05$; β=-0.1787, $p<0.05$) and maximum force of right forefoot and midfoot significantly increased total fat mass (β=0.04401, $p<0.01$; β=0.0355, $p<0.05$).

Mediolateral displacement of CoP intersection point, length of CoP path during right stance phase and single stance phase, maximum force of right forefoot and right heel and contact time of right midfoot and right heel explained 92% of the accounted variability of fat-free mass (F(7, 10) = 17.36, $p<0.001$) and R^2 obtained for the validation group was 82%. Mediolateral displacement and maximum, force of right heel and contact time of right midfoot significantly increased fat-free mass (β=0.471, $p<0.05$; β=0.0583, $p<0.01$; β=0.366, $p<0.05$) and contact time of right heel significantly decreased fat-free mass (β=-0.4392, $p<0.01$)

Mediolateral displacement of CoP intersection point, length of CoP path during right stance phase, maximum force of right forefoot and right midfoot, and contact time of right forefoot explained 89% of the accounted variability of right arm fat mass of (F(5, 12) = 19.07, $p<0.001$) and R^2 obtained for the validation group was 92%. Mediolateral displacement, length of CoP path and contact time of right forefoot significantly decreased right arm fat mass ($\beta=-0.0683$, $p<0.05$; $\beta=-0.02673$, $p<0.001$; $\beta=-0.1005$, $p<0.05$) and maximum force of right forefoot and right midfoot significantly increased right arm fat mass ($\beta=0.003327$, $p<0.01$; $\beta=0.004193$, $p<0.001$).

Walking speed, mediolateral displacement of CoP intersection point, length of CoP path during right stance phase and maximum force of right forefoot and right midfoot explained 87% of the accounted variability of trunk fat mass of (F(5, 12) = 16.28, $p<0.001$) and R^2 obtained for the validation group was 73%. Mediolateral displacement and length of CoP path significantly decreased trunk fat mass ($\beta=-0.450$, $p<0.05$; $\beta=-0.0907$, $p<0.05$) and maximum force of right forefoot and right midfoot significantly increased trunk fat mass ($\beta=0.02551$, $p<0.001$; $\beta=0.01917$, $p<0.05$).

Walking speed, mediolateral displacement of CoP intersection point, length of CoP path during right stance phase, maximum force of right forefoot and right midfoot, and contact time of right forefoot explained 89% of the accounted variability of right leg fat mass of (F(6, 11) = 14.25, $p<0.001$) and R^2 obtained for the validation group was 87%. Mediolateral displacement and length of CoP path significantly decreased right leg fat mass ($\beta=-0.1171$, $p<0.05$; $\beta=-0.0372$, $p<0.01$) and maximum force of right forefoot and right midfoot significantly increased right leg fat mass ($\beta=0.00639$, $p<0.01$; $\beta=0.00613$, $p<0.01$).

Mediolateral displacement of CoP intersection point, length of CoP path during right stance phase and maximum force and contact time of right heel explained 84% of the accounted variability of right arm fat-free mass (F(4, 13) = 17.69, $p<0.001$) and R^2 obtained for the validation group was 80%. Mediolateral displacement, length of CoP path and maximum force of right heel significantly increased right arm fat-free mass ($\beta=0.0557$, $p<0.01$; $\beta=0.00798$, $p<0.05$; $\beta=0.003294$, $p<0.001$) and contact time of right heel significantly decreased right arm fat-free mass ($\beta=-0.04112$, $p<0.001$).

Mediolateral displacement of CoP intersection point, length of CoP path during right stance phase and maximum force and contact time of right heel explained 80% of the accounted variability of trunk fat-free mass (F(4, 13) = 13.13, $p<0.001$) and R^2 obtained for the validation group was 99%. Mediolateral displacement, length of CoP path and maximum force of right heel significantly increased trunk fat-free mass ($\beta=0.297$, $p<0.05$; $\beta=0.0508$, $p<0.05$; $\beta=0.02369$, $p<0.001$) and contact time of right heel significantly decreased trunk fat-free mass ($\beta=-0.2112$, $p<0.01$).

Length of CoP path during right single support phase and maximum force and contact time of right heel explained 76% of the accounted variability of right leg fat-free mass (F(3, 14) = 15.00, $p<0.001$) and R^2 obtained for the validation group was 67%. Length of CoP path during right single support phase maximum force of right heel significantly increased right leg fat-free mass (β=0.02078, $p<0.05$; β=0.00996, $p<0.001$) and contact time of right heel significantly decreased right leg fat-free mass (β=-0.0462, $p<0.05$).

3.7.2 Women

The multiple regression for women was calculated to predict body composition based on their gait parameters, which were only measured on the right side. All model was significant (all $p<0.05$), as shown in Table 9.

Anteroposterior and mediolateral displacement of CoP intersection point, length of CoP path during right stance phase and contact time of right forefoot and right heel explained 76% of the accounted variability of height (F(5, 12) = 7.80, p=0.002) and R^2 obtained for the validation group was 87%. Anteroposterior displacement, length of CoP path during right stance phase and contact time of right forefoot and right heel significantly increased height (β=1.339, $p<0.05$; β=0.2075, $p<0.05$; β=1.678, $p<0.05$; β=0.432, $p<0.01$) and mediolateral displacement significantly decreased height (β=-2.217, $p<0.01$).

Walking speed, the maximum force of right forefoot, the contact time of right midfoot, and right heel explained 91% of the accounted variability of weight (F(4, 13) = 32.83, $p<0.001$) and R^2 obtained for the validation group was 100%. Walking speed and contact time of right heel significantly decreased weight (β=-3.38, $p<0.05$; β=-0.281, $p<0.05$) and maximum force of right forefoot and contact time of right midfoot significantly increased weight (β=0.07178, $p<0.001$; β=0.589, $p<0.01$)

Stride length, anteroposterior and mediolateral displacement of CoP intersection point, length of CoP path during right stance phase, maximum force of right forefoot and right midfoot, and contact time of right midfoot and right heel explained 95% of the accounted variability of BMI (F(8, 9) = 22.86, $p<0.001$) and R^2 obtained for the validation group was 89%. Mediolateral displacement and maximum force of right forefoot and right midfoot significantly increased BMI (β=0.324, $p<0.05$; β=0.01654, $p<0.001$; β=0.01725, $p<0.05$) and length of CoP path and contact time of right heel significantly decreased BMI (β=-0.0505, $p<0.01$; β=-0.1474, $p<0.01$).

Walking speed, length of CoP path during right single support phase and the maximum force and the contact time of right forefoot explained 76% of the accounted variability of total fat mass (F(4, 13) = 10.27, p=0.001) and R^2 obtained for the validation group was 61%. Walking speed and the maximum force of right forefoot significantly increased total fat mass (β=4.49, $p<0.05$; β=0.0569, $p<0.01$) and length of CoP path significantly decreased total fat mass (β=-0.2940, $p<0.01$).

The maximum force of right forefoot explained 35% of the accounted variability of fat-free mass (F(1, 16) = 8.60, p=0.01) and significantly increased fat-free mass by 0.0361 ($p<0.05$). R^2 obtained for the validation group was 38%.

Length of CoP path during right single support phase and the maximum force of right forefoot explained 56% of the accounted variability of right arm fat mass (F(2, 15) = 9.49, p=0.002) and R^2 obtained for the validation group was 36%. Length of CoP path significantly decreased right arm fat mass (β=-0.01320, $p<0.05$) and the maximum force of right forefoot significantly increased right arm fat mass (β=0.002259, $p<0.01$).

Walking speed, length of CoP path during right single support phase and the maximum force and contact time of right forefoot explained 80% of the accounted variability of trunk fat mass (F(4, 13) = 13.29, $p<0.001$) and R^2 obtained for the validation group was 62%. Walking speed and maximum force of right forefoot significantly increased trunk fat mass (β=2.266, $p<0.05$; β=0.02912, $p<0.01$) and length of CoP path significantly decreased trunk fat mass (β=-0.1632, $p<0.001$).

Length of CoP path during right single support phase and the maximum force of right forefoot explained 49% of the accounted variability of right leg fat mass (F(2, 15) = 7.31, p=0.006) and R^2 obtained for the validation group was 53%. Length of CoP path during right single support phase significantly decreased right leg fat mass (β=-0.0292, $p<0.05$) and maximum force of right forefoot significantly increased right leg fat mass (β=0.00493, $p<0.01$).

Anteroposterior displacement of CoP intersection point and the maximum force of right forefoot explained 53% of the accounted variability of right arm fat-free mass (F(2, 15) = 8.53, p=0.003) R^2 obtained for the validation group was 82%. The maximum force of right forefoot significantly increased right arm fat-free mass (β=0.003650, $p<0.01$).

Stride length, length of CoP path during right single support phase, the maximum force of right forefoot and the contact time of right heel explained 75% of the accounted variability of trunk fat-free mass (F(4, 13) = 9.60, p= 0.001) and R^2 obtained for the validation group was 96%. Stride length and the contact time of right heel significantly decreased trunk fat-free mass (β=-0.1509, $p<0.01$; β=-0.1654, $p<0.05$) and length of CoP path and maximum force of right forefoot significantly increased (β=0.0592, $p<0.05$; β=0.02648, $p<0.001$).

Maximum force of right heel explained 38% of the accounted variability of right leg fat-free mass (F(1, 16) = 9.64, p=0.007) and significantly increased right arm fat-free mass by 0.01280 ($p<0.01$). R^2 obtained for the validation group was 38%.

Table 8. Multiple regression analysis for body composition (Men).

Regression model (Men)	R^2	R^2_{adj}	F-value	P-value
Height= 156.0 + 0.1640 LoS_R - 0.0213 MF_F_R + 0.0617 MF_H_R** - 0.202 C_M_R	0.68	0.58	6.80	0.004
Weight = 16.87 - 4.12 T_V* + 0.0649 MF_F_R*** + 0.03488 MF_M_R**+ 0.0305 MF_H_R	0.94	0.92	46.88	<0.001
BMI = 41.29 - 0.1089 T_C* - 0.1029 LoG_R** + 0.01907 MF_F_R*** + 0.01635 MF_M_R**	0.84	0.80	17.67	<0.001
BFM = 34.3 - 3.93 T_V - 0.909 ML_SD* - 0.1787 LoG_R* + 0.04401 MF_F_R**+ 0.0355 MF_M_R*	0.87	0.81	15.57	<0.001
FFM = -9.4 + 0.471 ML_SD* + 0.0854 LoG_R + 0.1142 LoS_R + 0.00285 MF_F_R + 0.0583 MF_H_R** + 0.366 C_M_R* - 0.4392 C_H_R**	0.92	0.87	17.36	<0.001
BFM RA = 13.19 - 0.0683 ML_SD* - 0.02673 LoG_R*** + 0.003327 MF_F_R**+ 0.004193 MF_M_R*** - 0.1005 C_F_R*	0.89	0.84	19.07	<0.001
BFM TR = 15.83 - 2.32 T_V - 0.450 ML_SD* - 0.0907 LoG_R* + 0.02551 MF_F_R*** + 0.01917 MF_M_R*	0.87	0.82	16.28	<0.001
BFM RL = 20.52 - 0.324 T_V - 0.1171 ML_SD* - 0.0372 LoG_R** + 0.00639 MF_F_R**+ 0.00613 MF_M_R** - 0.1521 C_F_R	0.89	0.82	14.25	<0.001
FFM RA = 1.886 + 0.0557 ML_SD** + 0.00798 LoG_R* + 0.003294 MF_H_R*** - 0.04112 C_H_R***	0.84	0.80	17.69	<0.001
FFM TR = 13.08 + 0.297 ML_SD* + 0.0508 LoG_R* + 0.02369 MF_H_R** - 0.2112 C_H_R***	0.80	0.74	13.13	<0.001
FFM RL = 4.76 + 0.02078 LoS_R* + 0.00996 MF_H_R*** - 0.0462 C_H_R*	0.76	0.71	15.00	<0.001

Note. G_SRL: Stride length; T_SR: Stride time; T_Cadence: Cadence; T_Velocity: Walking speed; AP_SD and ML_SD: Anteroposterior and mediolateral displacement of CoP intersection point; LoG_R and LoS_R: Right length of the butterfly diagram during stance phase and during single support phase; MF_F_R, MF_M_R and MF_H_R: Maximum force of right forefoot, midfoot and heel; C_F_R, C_M_R and C_H_R: Contact time of right forefoot, midfoot and heel; BMI: Body mass index; BFM: Total fat mass; FFM: Total fat-free mass; RA: Right arm; TR: Trunk; RL: Right leg.

***: P < 0.5**

****: P < 0.01**

*****: P < 0.001**

Table 9. Multiple regression analysis for body composition (Women).

Regression model (Women)	R^2	R^2_{adj}	F-value	P-value
Height= -56.2 + 1.339 AP_SD* - 2.217 ML_SD** + 0.2075 LoG_R* + 1.678 C_F_R* + 0.432 C_H_R**	0.76	0.67	7.8	0.002
Weight = -1.58 - 3.38 T_V* + 0.07178 MF_F_R*** + 0.589 C_M_R** - 0.281 C_H_R*	0.91	0.88	32.93	<0.001
BMI = 20.44 + 0.0032 G_SRL - 0.249 AP_SD + 0.324 ML_SD* - 0.0505 LoG_R** + 0.01654 MF_F_R*** + 0.01725 MF_M _R* + 0.1018 C_M_R - 0.1474 C_H_R **	0.95	0.91	22.86	<0.001
BFM = 193.7 + 4.49 T_V * - 0.2940 LoS_R** + 0.0569 MF_F_R** - 2.15 C_F_R	0.76	0.69	10.27	0.001
FFM = 18.84 + 0.0361 MF_F_R*	0.35	0.31	8.60	0.010
BFM RA = 1.103 - 0.01320 LoS_R* + 0.002259 MF_F_R**	0.56	0.50	9.49	0.002
BFM TR = 97.8 + 2.266 T_V* - 0.1632 LoS_R*** + 0.02912 MF_F_R**- 1.075 C_F_R	0.80	0.74	13.29	0.000
BFM RL = 2.78 - 0.0292 LoS_R* + 0.00493 MF_F_R**	0.49	0.43	7.31	0.006
FFM RA = -0.613 + 0.0941 AP_SD + 0.003650 MF_F_R**	0.53	0.47	8.53	0.003
FFM TR = 21.94 - 0.1509 G_SRL** + 0.0592 LoS_R* + 0.02648 MF_F_R*** - 0.1654 C_H_R*	0.75	0.67	9.60	0.001
FFM RL = 1.42 + 0.01280 MF_H_R*	0.38	0.34	9.64	0.007

Note. G_SRL: Stride length; T_SR: Stride time; T_Cadence: Cadence; T_Velocity: Walking speed; AP_SD and ML_SD: Anteroposterior and mediolateral displacement of CoP intersection point; LoG_R and LoS_R: Right length of the butterfly diagram during stance phase and during single support phase; MF_F_R, MF_M_R and MF_H_R: Maximum force of right forefoot, midfoot and heel; C_F_R, C_M_R and C_H_R: Contact time of right forefoot, midfoot and heel; BMI: Body mass index; BFM: Total fat mass; FFM: Total fat-free mass; RA: Right arm; TR: Trunk; RL: Right leg.

*: $P < 0.5$

**: $P < 0.01$

***: $P < 0.001$

4. DISCUSSION

4.1 Emotional response

According to the circumplex model (Russell, 1980), joy could be positive emotion involving high valence and high arousal, while sadness could be negative emotion involving low valence and low arousal, and neutral emotion could represent the midpoint for the intensity of emotional valence and arousal. In this study, the intensity of valence after the three tasks increased in the order of sadness, neutral, and joy. Therefore, the intensity of valence well induced by each video clip following the circumplex model.

However, there was a different trend in the intensity of arousal. First, the intensity of arousal was the lowest after the neutral task, with a significant difference between the intensity of arousal before the task and after task inducing neutral emotion. This result was consistent with previous research which used video clip to induced emotion (Brandão et al., 2016). In previous research, the neutral video contained a similar scene with this study. Both neutral stimuli were the relatively static video clips, which contained only sounds and scenes of flowing water in contrast to joy or sad video clips, which contained scenes from entertainment and documentary programs. Therefore, the participants responded to the lowest arousal with a calm state.

Second, there were no differences between the intensity of arousal before and after the sadness task in both genders, although it was lower than the midpoint of the 9-point scale. The mean intensity of arousal was low throughout the entire experiment period, and sadness stimuli contained relatively slow contents, so that viewing short-duration video-clip of two minutes would be not enough to cause a significant decrease in intensity of arousal.

Third, the average intensity of arousal after watching the video clip inducing joy emotion did not exceed the midpoint of the 9-point scale in both genders. Most participants have watched the video clip because it was from a popular entertainment program, so the video clip probably triggered a relatively low change in the intensity of arousal.

Furthermore, there was a gender effect on the intensity of increase or decrease in valence and arousal compared to the intensity of those before task, as shown in Figure 15. Women reported more negative valence for sadness stimulus and more positive valence for joy stimulus and presented calmer for neutral stimulus and more excited for joy stimulus than men because women reported greater positive expressivity and negative expressivity than men when they watched positive and negative stimuli (Gross & John, 1998; Kring & Gordon, 1998).

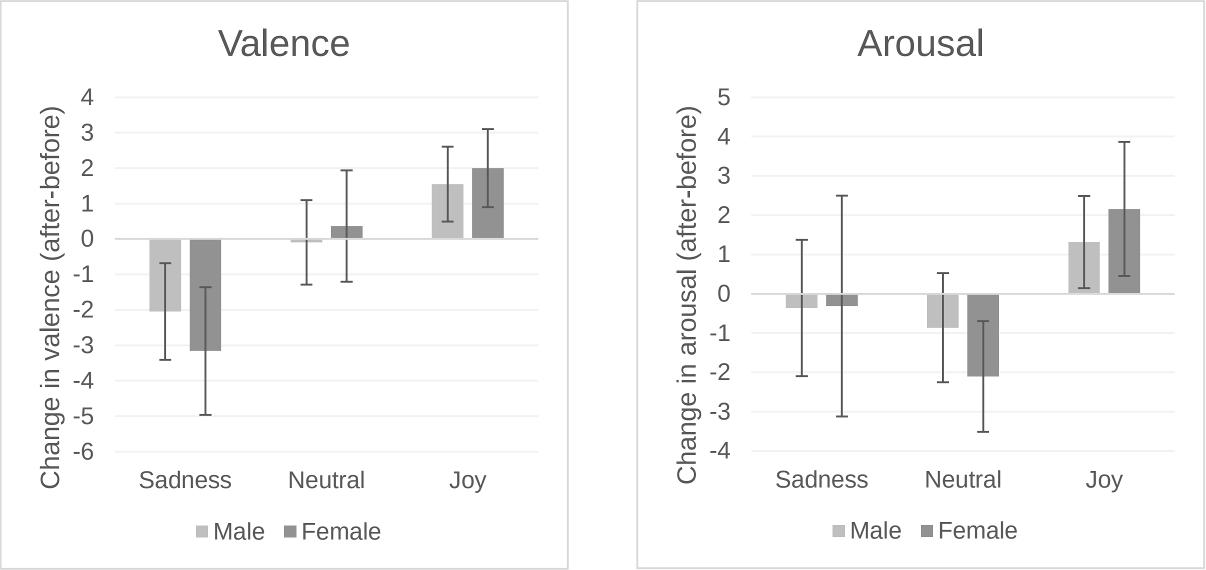


Figure 15. Change in intensity of valance (left) and arousal (right).

4.2 Association of emotion with gait patterns

In the order of sadness, neutral, and joy, step length, cadence, walking speed, percentage of swing phase, length of CoP path during single support phase and the 2nd maximum force significantly increased, and step time and percentage of stance and double support phase significantly decreased in both genders. This inclination was similar to the trend of the intensity of valence with changes in emotions in both genders. Thus, the result suggested that the intensity of valence may have more influence on the change in gait patterns than the intensity of arousal in all variables except mediolateral displacement of CoP intersection point and the 1st maximum force, which had a different result depending on gender.

The effect of emotion (sadness vs. joy) on gait patterns was the same in both genders. In men, only stride length significantly differed in three emotions (sadness vs. neutral vs. joy), and others were not significant between sadness and neutral emotion. Time variables, including cadence, walking speed, and step time, had a large effect. On the other hand, in women, all spatiotemporal parameters and phase parameters significantly differed in three emotions, and most gait parameters had a large effect size. This difference would be because women expressed more negative for sadness stimulus, and women tended to be more progressively away from unpleasant stimuli (Hillman, Rosengren, & Smith, 2004).

4.2.1 Spatiotemporal parameters

Joy increased stride length, cadence, and walking speed and decreased step time compared to sadness. It was consistent with previous studies that described change in gait parameters related to increased walking speed in pleasant emotion induced by any methods such as affective picture, auditory stimulus and recalling autobiography (Barliya et al., 2013; Kang, 2017; Kang & Gross, 2016; Kang et al., 2018; Michalak et al., 2009; Naugle, Joyner, Hass, & Janelle, 2010; Park et al., 2019).

During a whole gait cycle (100%), the percentage of stance phase and double support phase were reduced, and the swing phase was increased for joy than sadness, which was similar to the previous study that manifested the increase of swing phase in joy compared to sadness was 4% (Barliya et al., 2013).

All spatiotemporal parameters have been affected by the walking speed. As a result, as the speed increases, stride length, and cadence increased (Kirtley, Whittle, & Jefferson, 1985). Therefore the stance and double support phase decreased, and the swing phase increased with higher walking speed (Hebenstreit et al., 2015).

4.2.2 CoP parameters

The length of the CoP path during single support phase from foot flat to heel off was significantly different between sadness and joy in men and women, while the length of the CoP path during stance phases was not significantly different between emotions. Walking with joy increased the length of the CoP path than sadness. The length of the CoP path was mostly dependent on landing strategy; the longer the length, the more likely the heel strike strategy was to be used, and the shorter the length, the more likely the flat foot strategy was to be used (Magyari et al., 2017).

In only men, mediolateral displacement of the CoP intersection point significantly differed between sadness and joy, and it was higher when feeling sadness. According to the previous study, joy decreased lateral sway in upper body movement despite increased walking speed (Michalak et al., 2009), which was opposite to widespread knowledge that decreased walking speed was associated with less lateral sway of the upper body with a forward inclination of the trunk (THORSTENSSON, NILSSON, CARLSON, & ZOMLEFER, 1984). Both the center of pressure and center of mass contributed to postural control while walking (Błaszczyk J.W., 2008). Specifically, the mediolateral displacement of CoP was a characteristic that represents the mediolateral stability of the foot. Therefore, the greater displacement in sadness emotion indicated a lack of body balance (Gefen, Megido-Ravid, Itzchak, & Arcan, 2002) which caused by additional attention demands due to more substantial initial attention with unpleasant contents (Chen & Qu, 2017). In other words, walking while feeling joy emotion could be presented as maintaining relatively stable gait patterns by increasing the amount of the somatosensory input with increased length of CoP path during the single support phase.

4.2.3 Force parameters

The 1st peak force and 2nd peak force was bigger, and time to 1st peak was shorter in joy compared to sadness. The 1st peak force appeared at the start of the single support phase after heel strike, and 2nd peak force appeared at the end of the single support phase. The result was similar to previous research, which studied the effect of mood on gait patterns with bipolar disorder (Kang et al., 2018). In the previous study, the researcher found the hypomanic group produced greater peak braking force, push-off force and vertical force and generated higher peak knee and ankle power during gait, while the depressed group produced less force and power. Although the change in gait patterns due to the mood phase would be less apparent than emotional change, the result showed the same change of gait patterns. The higher arousal emotion (joy) was similar to the hypomanic phase (Munley, Bains, Frazee, & Schwartz, 1994) and the low arousal emotion (sadness) was similar to the depressed phase (Feldman, 1995). Through the same changes from the two results, for higher valence emotion, participants walked more energetic with greater peak force and faster speed.

4.2.4 Speed effect

Walking speed presented the largest effect size in both genders as the effect of change in emotion. Walking speed affect other gait parameters including spatiotemporal parameters, CoP parameters and force parameters (Barliya et al., 2013; Chung & Wang, 2012; Cook, Farrell, Carey, Gibbs, & Wiger, 1997; Hebenstreit et al., 2015; Kirtley et al., 1985). However, as shown in Figure 16 (men) and Figure 17 (women), the slopes of the regression line between walking speed and each gait parameters were differed for each emotion, so that additional changes in gait patterns were caused not solely by a changed in walking speed.

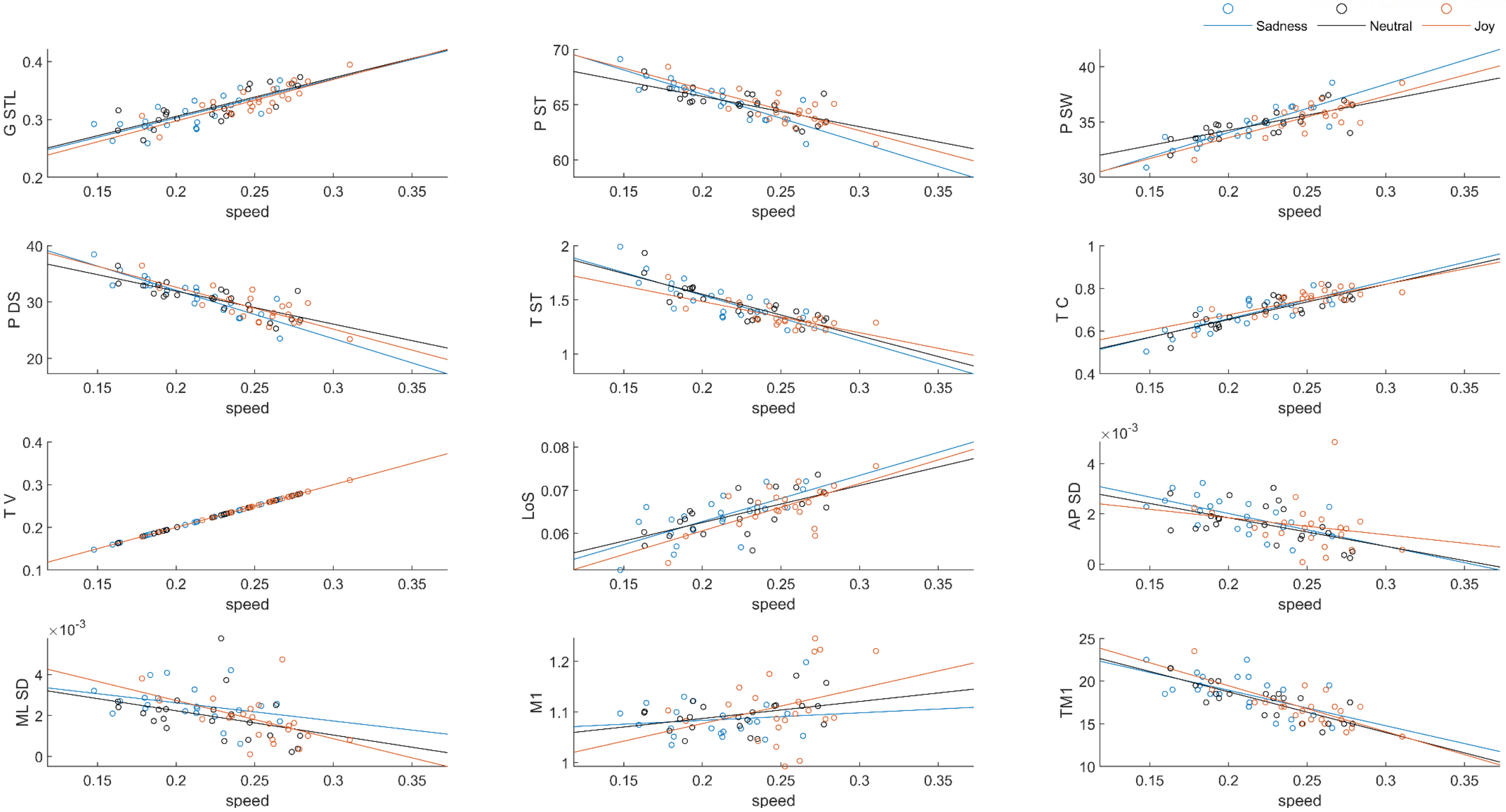


Figure 16. The effect of speed on gait parameters during emotional walking in men. The dot plot presents the scatter between speed and gait parameters, and the line plot was linear regression prediction line. Blue: sadness; Black: neutral; Orange: joy; G_STL: Step length; P_ST: Stance phase; P_SW: Swing phase; P_DS: Double support phase T_ST: Step time; T_C: Cadence; T_V: Walking speed; LoS: Length of the butterfly diagram during stance phase and during single support phase; AP_SD and ML_SD: Anteroposterior and mediolateral displacement of CoP intersection point; M1 and M2: the 1st and the 2nd peak force of average gait cycle; TM1: Time to the 1st peak force.

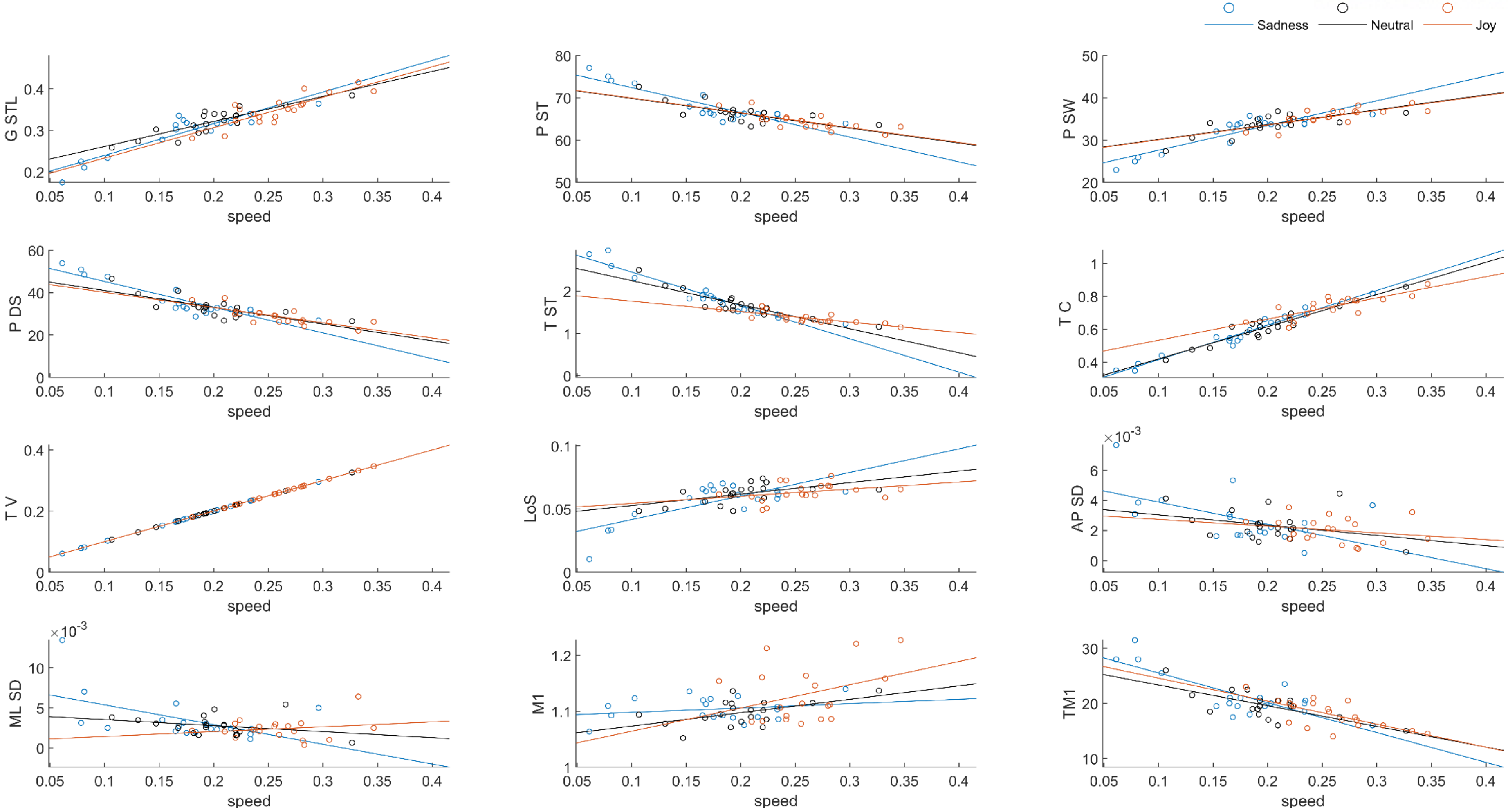


Figure 17. The effect of speed on gait parameters during emotional walking in women. The dot plot presents the scatter between speed and gait parameters, and the line plot was linear regression prediction line. Blue: sadness; Black: neutral; Orange: joy; G_STL: Step length; P_ST: Stance phase; P_SW: Swing phase; P_DS: Double support phase T_ST: Step time; T_C: Cadence; T_V: Walking speed; LoS: Length of the butterfly diagram during stance phase and during single support phase; AP_SD and ML_SD: Anteroposterior and mediolateral displacement of CoP intersection point; M1 and M2: the 1st and the 2nd peak force of average gait cycle; TM1: Time to the 1st peak force.

4.3 Association between physical activity, body composition and gait patterns

4.3.1 Physical activity

The intensity of physical activity showed no significant relationship in most variables of body composition and gait patterns because most of the participants recruited from the university community lived in dormitories, so they had similar lifestyles.

In men, higher total physical activity was correlated with shorter stride time, greater cadence, and increased mediolateral displacement of the CoP intersection point. The higher moderate recreational activity was correlated with an increased mediolateral displacement of the CoP intersection point. There was no correlation between physical activity and body composition. According to the previous research, an increase in physical activity level presented increased stride length and stride velocity. However, the increased mediolateral displacement was inconsistent with the previous study that showed increased physical activity contributed better balance (Santos et al., 2016).

In women, there was no correlation between the intensity of physical activity and gait parameters. The only time to sedentary behavior negatively correlated with body composition, total fat mass, right arm fat mass, trunk fat mass, and right leg fat mass which was inconsistent with prevalence knowledge (Bullock, Griffiths, Sherar, & Clemes, 2017; Chau, van der Ploeg, Merom, Chey, & Bauman, 2012).

4.3.2 Correlation between body composition and gait parameters

In men, height was strongly correlated with right leg fat-free mass, so that the correlation between height and gait parameters was similar between right leg fat-free mass and gait parameters.

Height and right leg fat-free mass had a commonly positive correlation with stride length, walking speed, and length of CoP path during the right stance phase and single support phase, and they had a negative correlation with anteroposterior of CoP intersection point.

Correlation between height and stride length and walking speed had been studied before. In the study of Samson et al. (2001), the height also correlated with stride length and walking speed when the participants walked on 12m wooden walkway. The result in this study supported their suggestion that slower speed would be associated with lower muscle strength. Therefore, it could be concluded that a tall person walks faster with longer stride length, which was related to a lot of leg fat-free mass.

Correlation between the length of the CoP path during the right stance phase and body composition was found in height and total and segmental fat-free mass except for right arm fat-free mass, which was only variable that not correlated with height among fat-free mass variables. The length of the CoP path was affected by foot length and walking strategy. Of the two CoP variables, the length of the CoP path during the stance phase would be more affected by foot length than the length of the CoP path during single support phase because it contained all path of CoP from heel strike to toe-off. Foot length was estimated by height, and two variables were correlated with each other (Giles & Vallandigham, 1991). Therefore, fat-free mass variables correlated with height increased the length of CoP during the stance phase with longer foot length.

In contrast, a correlation between the length of the CoP path during the right single support phase and body composition described in only height and right leg fat-free mass. The length of the CoP path during the right single support phase was affected by the walking strategy rather than the effect of foot length. According to the previous study, the leg fat-free mass increased max heel clearance (Y.G. Lee & Shin, 2018) so that individuals with higher leg fat-free mass would walk by heel strike strategy. Therefore, only leg fat-free mass and presented a longer length of CoP during the single support phase.

Displacement of CoP was a characteristic that represents the stability of the foot (Gefen et al., 2002). Increased right leg fat-free mass were correlated the less anteroposterior displacement. It indicated that leg fat-free mass contributed to body balance in the only anteroposterior direction. The anteroposterior balance was controlled by hip extensor and flexors, while the mediolateral balance was controlled dominantly by hip abductors and minorly hip adductors (Winter, 1995). Consequently, a different effect on both directions depended on muscle development. However, since fat-free mass did not provide information on muscle distribution and each muscle activation, it was difficult to identify the direct impact on postural balance. Therefore, studies of muscle activity may need to be carried out later.

Increased height provided better body balance in both directions. It was inconsistent with Alonso et al. (2012), which showed a positive correlation between height and postural sway in both genders and consistent with Kim et al. (2012), which showed a negative correlation between height and anteroposterior displacement of CoP intersection point in men. Two studies analyzed postural sway during static stance. While walking, there was research about the effect of height on the displacement of the center of mass (CoM). Based on an inverted pendulum model, a taller person had a higher position of CoM, and it made larger sway than a shorter person (Winter, 1995). However, the inclination angle between CoM and CoP was not affected by height while walking (H. J. Lee & Chou, 2006), which indicated there would be different tendencies between change in CoM and CoP. According to Gary P. Jacobson (2014), a taller person had a wider spacing between the feet to keep their postural balance while a shorter person could place feet closer together. Different walking strategies in taller individuals made an increased limit of stability, and it would have resulted in the smaller displacement of the CoP intersection point.

The height which did not correlate with weight was correlated with only the maximum force of heel. Height was strongly correlated with leg fat-free mass, which also had a positive correlation with the maximum force of heel. Higher leg fat-free mass was predicted by the maximum heel clearance, which was vertical movement distance of heel from toe-off to heel contact during the swing phase (Y. G. Lee & Shin, 2018). Thus, the greater maximum force of heel may have been produced by lowering the legs at a higher height.

Weight was correlated with all variables except height, and it presented a higher correlation with fat mass than fat-free mass, which were not correlated to each other.

Weight presented a strong correlation with the maximum force of forefoot and heel and was moderately correlated with midfoot. The maximum force of midfoot was relatively smaller than others because the arch structure of foot made different force distribution depended on the walking strategy, which shifted their CoP to more medial foot position or lateral foot position. Thus, the effect of weight on midfoot would be smaller than in other zones.

As total and segmental total fat mass increased, the maximum force of forefoot, midfoot, and heel was increased similar to weight. On the contrary, the total and segmental fat-free mass did not present a correlation with the maximum force of midfoot. As mentioned earlier, the midfoot was influenced by the walking strategy, so a larger total fat-free mass would have had another effect, presenting not only a mass increase but another walking strategy.

The BMI was correlated with the maximum force of forefoot and midfoot. The BMI was negatively correlated with height and positively correlated with weight. Therefore, it was not correlated with the maximum force of heel.

In women, height was correlated with total and segmental fat-free mass. Contrary to men, height was correlated with weight so that the significant correlation result would be different to men. Weight was correlated with the maximum force of forefoot and heel. The maximum force of midfoot did not show the correlation. It would be that women walked with more flexed-adducted-internally rotated hip joint and more valgus knee joint (i.e., knock knees)), which more contacting medial foot (Motooka, Tanaka, Ide, Mawatari, & Hotokebuchi, 2012). Therefore, despite the increased weight, the load was applied to the arch structure of midfoot so that it made no effect on the maximum force of midfoot.

Weight, BMI, and total and segmental fat mass, which were intercorrelated with each other, were correlated with the contact time of forefoot and midfoot, which was not correlated in men. It would be because women walked with the more anterior-tilted pelvis, which affected contact time. According to previous research (da Silva-Hamu et al., 2013), obese women showed delayed in the gait cycle with joint overexertion. In the terminal swing phase, the moment of inertia occurred when it moves forward. The increased mass, which directly proportional to the moment of inertia, made pendular movements tend to deteriorate with higher exertion of knee flexor muscles and greater ankle torque. Therefore, to maintain the body balance against the increased moment of inertia, the contact time of midfoot and forefoot would be increased.

4.4 Multiple regression prediction model

The purpose of the multiple regression model was to determine the best predictors of each body composition using gait parameters. Using multiple predictors to evaluate changes in body composition would be more valuable than conducting a correlation between two variables because changes in a person's body composition can be affected directly or indirectly by various walking factors.

4.4.1 Men

All body composition predicting models were significant with high R^2 in prediction and validation groups. It means the model was well fitted between the actual value and predicted value.

The only maximum force of heel predicted 68% of the variance in height. The relationship between height and the maximum force of heel has been previously discussed in the literature (see discussion of the correlation between body composition and gait parameters).

A combination of walking speed and maximum force of forefoot and midfoot predicted 94% of the variance in weight. All variables except walking speed had a direct effect, and it had been discussed. Walking speed has not been directly associated with a change in height, which has been predicted in previous research. According to Tolea et al. (2012), model adjusted for year, baseline gait speed, age, race, study site, education, and height predicted walking speed decline as an increase in weight.

A combination of cadence, length of CoP path during the stance phase, and maximum force of midfoot and heel predicted 84% of the variance in BMI. The maximum force of forefoot and heel had been discussed. Cadence and length of the CoP path during the stance phase have not been directly associated with a change in BMI. In the study of da Silva-Hamu et al. (2013), obesity, which indicated by higher body mass index, presented lower cadence. In another study, there was no difference in knee adduction moment, but walking speed decreased in obese (Freedman Silvernail et al., 2013). It was because when individuals with higher body mass index walked at decreased walking speed, they showed stiff-knee gait with less peak knee adduction angle. With less knee adduction angle, the foot contact would be more medially (Motooka et al., 2012). These different gait patterns occurred decreased length of the CoP path during the right stance phase.

A combination of mediolateral displacement of CoP intersection point and length of CoP path during the stance phase and the maximum force of forefoot and midfoot predicted 87%, 89%, 87%, and 89% of the variance in the total fat mass right arm, trunk and right leg fat mass. The maximum force of forefoot and maximum force of midfoot had a direct effect, and it had been discussed. Mediolateral displacement of the CoP intersection point and length of the CoP path during the stance phase have not been directly associated with the change in total fat mass. There would be a confounder effect of those with predictors of maximum fore of forefoot and heel to predict fat mass. The study about the effect of total and segmental fat mass on CoP parameters while walking was limited. Therefore, it needed to further research.

A combination of mediolateral displacement of CoP intersection point and maximum force of heel and contact time of midfoot and heel predicted 92% of the variance in total fat-free mass. The maximum force of heel had been discussed. Other variables have not been directly associated with a change in total fat-free mass. Mediolateral displacement was positively correlated with lean mass in men during the postural balance test (A. C. Alonso et al., 2015; Angélica Castilho Alonso et al., 2012). Total fat-free mass would increase to generate more muscle force controlling increased body sway. In addition, while generating more muscle force to reduce the body sway, it would increase the contact time of midfoot and reduce the contact time of heel.

A combination of mediolateral displacement of CoP intersection point and length of CoP path during stance phase and maximum force of heel and contact time of heel predicted 84% and 80% of the variance in right arm and trunk fat-free mass. The maximum force of heel had a direct effect, and it had been discussed. Mediolateral displacement of CoP intersection point and length of CoP path during the stance phase and contact time of heel have not been directly associated with a change in right arm and trunk fat-free mass. Similar effect mediolateral displacement of CoP intersection point to total fat-free mass would be shown in the right arm and trunk fat-free mass. With the movement to reduce body sway, the fat-free mass would be contributed to shifting the CoP medially.

A combination of the length of the CoP path during the single support phase and the maximum force and contact time of heel predicted 76% of the variance in right leg fat-free mass. All variables except contact time of heel had a direct effect, and it had been discussed.

4.4.2 Women

A combination of anteroposterior and mediolateral displacement of the CoP intersection point and length of the CoP path during the stance phase and the contact time of forefoot and heel predicted 76% of the variance in height. Mediolateral displacement of the CoP intersection point and length of the CoP path during the stance phase had a direct effect, which had been discussed. Anteroposterior displacement of the CoP intersection point and the contact time of forefoot and heel have not been directly associated with a change in height.

A combination of walking speed, the maximum force of forefoot, and the contact time of midfoot and heel predicted 91% of the variance in weight. The maximum force of forefoot and the contact time of midfoot had a direct effect. Walking speed and the contact time of heel have not been directly associated with a change in weight, but the previous study found the relationship between walking speed and weight in women (Samson et al., 2001).

A combination of mediolateral displacement of the CoP intersection point, length of the CoP path during the stance phase, the maximum force of forefoot and midfoot, and contact time of heel predicted 95% of the variance in the BMI. The maximum force of forefoot and midfoot had a direct effect. Mediolateral displacement of the CoP intersection point, length of the CoP path during the stance phase, and contact time of heel have not been directly associated with the change in BMI.

A combination of walking speed and length of the CoP path during single support phase and maximum force of forefoot predicted 76% and 80% of the variance in total fat mass and trunk fat mass. All variables except walking speed had a direct effect. Walking speed has not been directly associated with a change in total fat mass.

The maximum force of forefoot predicted 35%, 55% and 38% of variance in total fat-free mass and right arm and right leg fat-free mass, which have been discussed. The combination stride length of and length of CoP path during single support phase and maximum force of forefoot and contact time of heel predicted 75% of the variance in trunk fat-free mass. The maximum force of forefoot had a direct effect. Stride length and length of CoP path during single support phase and contact time of heel have not been directly associated with the change in trunk fat-free mass of which study was limited.

A combination of the length of CoP path during single support phase and maximum force of forefoot predicted 56% and 49% of the variance in right arm and right leg fat mass. All variables had a direct effect except the effect of length of the CoP path during the single support phase on the right leg fat mass.

4.5 Limitations and future research

There were several limitations in current study. First, only three target emotions (sadness, neutral and joy) were included. The video clips that were studied to influence Korean emotions in previous studies were selected as an emotional stimulus. The video clip follows the circumflexed model with four stimuli, each divided by high and low intensity for arousal and valence. In the first pilot experiment, all four stimuli were included, and the participants participated in the experiment without knowing that it was an emotional experiment. After the experiment, several participants were asked to let them know that they would not be able to participate in the experiment if they can't see violent movies before the experiment, saying that the low valence high arousal stimulus was too violent so that they remembered for a long time. Therefore, the experiment was conducted with only stimuli representing high arousal and high valence and stimuli representing low arousal and low valence. However, previous studies have shown that low arousal high valence stimuli and high arousal low valence stimuli also have different walking patterns (Roether, Omlor, Christensen, & Giese, 2009). Therefore, if the study had been conducted with more diverse effects on emotional stimuli, it would have been more obvious to change the walking patterns for change in valence and arousal, which could have contributed to creating an emotional analysis model using plantar pressure distribution analysis.

Secondly, the relationship between studied walking patterns and emotional body expressions may not be consistent. In the experiment, the participants were instructed to walk while still recalling the video they watched before carrying out the walking task. In this process, participants would usually be able to recognize the intended effect. This can also be seen in subjective reports of emotional states. The participants probably tend to report stronger effects to suit the intent of the experimenter (Westermann, Spies, Stahl, & Hesse, 1996). In this study, after getting neutral to be carried out for the first time, the task of sadness and joy was to be carried out. By comparing neutral walking patterns with emotional walking patterns, there was a characteristic difference between their emotional body expressions. However, further research on the relationship between walking patterns and emotions will require more detailed monitoring of participants' emotional experiences to assess whether the target emotions were actually induced.

Third, in this study, the number of participants had insufficient to analyze the effect of body composition on walking patterns by multiple linear regression models. Because of the effects of gender, the group was divided into men and women, and furthermore, the analysis was conducted by dividing it into prediction and validation groups to validate the prediction regression model. It has resulted in a low correlation between the predicted and measured values within the validation group. However, since all predictive models have the effect size above moderate, this could help us understand the effects of body composition on gait patterns.

In addition, the linear prediction model included variables that had indirect effects. As a result of this experiment, it was difficult to find a confounding factor that could explain an indirect effect. There was also a lack of prior research on the association of body composition with gait patterns in young adults so that discussions on variables that had indirect effects had been limited. Therefore, further studies should be conducted with large samples and more diverse body composition. It will be necessary to divide groups according to body composition and study in more detail about the effect of body position on the planar pressure distribution.

4.6 Application

This study will help to understand the relationship between emotion, body composition, and walking patterns. Furthermore, it will be the basis for the development of a model that uses a pressure platform to predict an individual's emotional state and body composition. The model makes it easier and more accurate for stores to obtain customer information without privacy issues. It will be able to help build better services and contribute to providing individualized and optimal services to each customer.

5. CONCLUSION

The purpose of this study was to investigate the association of emotional state and body composition between gait patterns using a pressure platform. The result suggested that women were more affected by emotion change, especially in sadness. Women showed a significant difference between neutral and sadness, but the men did not. Both men and women presented significant differences between joy and sadness.

Walking while feeling joy increased spatiotemporal variables such as step length, cadence, and velocity, which decreased the percentage of stance phase and double support phase and increased swing phase during a whole gait cycle. The emotion was also associated with the CoP path and force. The length of the CoP path during the single support phase was increased during joyful walking. The first and second peak force during 100% of the gait cycle was increased, and time to the first peak was decreased in joy than sadness. Only for men, less mediolateral displacement of the CoP intersection point was presented.

Regarding the association of body composition between gait parameters, there was a direct effect and indirect effect. In the men, height and right leg fat-free mass had a commonly positive correlation with stride length, walking speed, and length of CoP path during the right stance phase and single support phase, and they had a negative correlation with anteroposterior of CoP intersection point. Weight and total and segmental fat mass presented a positive correlation with the maximum force of forefoot, midfoot, and heel. The body mass index (BMI) was correlated with the maximum force of forefoot and midfoot. Contrary to the men, in women, weight was not correlated with a maximum force of midfoot. Weight, BMI, and total and segmental fat mass, which were intercorrelated with each other, were correlated with the contact time of forefoot and midfoot.

As the indirect effect, in men, total and segmental fat mass (right arm, trunk and right leg fat mass) decreased by two CoP variables, mediolateral displacement of the CoP intersection point and length of the CoP path during the stance phase with direct effect of increased maximum force of right forefoot and right midfoot in regression prediction model. Total and segmental fat-free mass (right arm, trunk, and right leg fat mass) indirectly increased by the length of the CoP path during the stance phase and maximum force with the direct effect of decreased contact time of right heel.

In the women, most of the prediction regression model of fat mass and fat-free mass was explained by the directed effect. Total and segmental fat mass was explained by the decrease in length of CoP during the right single support phase and increase in the maximum force of forefoot, while total and segmental fat-free mass was explained by the increase in the maximum force of forefoot.

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APPENDICES

Appendix A

Full Analysis of Variance Tables

a. Emotional response (valence) after task

a.1 Men

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Valence_before	1	1.755	1.7548	2.1	0.155
Task	2	141.28	70.64	84.5	<0.001
Participant	21	25.567	1.2175	1.46	0.149
Error	41	34.275	0.836		
Total	65				

a.2 Women

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Valence_before	1	1.616	1.616	0.71	0.404
Task	2	177.246	88.623	39.08	<0.001
Participant	18	23.002	1.278	0.56	0.902
Error	35	79.367	2.268		
Total	56				

b. Emotional response (arousal) after task

b.1 Men

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Arousal_before	1	3.464	3.464	2.17	0.148
Task	2	56.215	28.108	17.6	<0.001
Participant	21	41.426	1.973	1.24	0.275
Error	41	65.476	1.597		
Total	65				

b.2 Women

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Arousal_before	1	6.309	6.309	2.63	0.114
Task	2	65.864	32.932	13.75	<0.001
Participant	18	61.394	3.411	1.42	0.181
Error	35	83.831	2.395		
Total	56				

c. Association of emotion with gait patterns

c.1 Men

Normalized step length

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	0.044012	0.002096	11.66	<0.001
Task	2	0.00682	0.00341	18.97	<0.001
Error	42	0.00755	0.00018		
Total	65	0.058382			

Normalized step time

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	1.239	0.059001	9.19	<0.001
Task	2	0.334	0.166986	26.02	<0.001
Error	42	0.2696	0.006418		
Total	65	1.8425			

Stance phase

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	106.45	5.069	5.98	<0.001
Task	2	12.36	6.1819	7.29	0.002
Error	42	35.62	0.8481		
Total	65	154.43			

Swing phase

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	106.45	5.069	5.98	<0.001
Task	2	12.36	6.1819	7.29	0.002
Error	42	35.62	0.8481		
Total	65	154.43			

Double support phase

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	404.87	19.28	5.39	<0.001
Task	2	71.03	35.515	9.93	<0.001
Error	42	150.28	3.578		
Total	65	626.18			

Cadence

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	0.23844	0.011354	10.04	<0.001
Task	2	0.0689	0.034451	30.46	<0.001
Error	42	0.04751	0.001131		
Total	65	0.35486			

Velocity

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	0.05633	0.002682	8.04	<0.001
Task	2	0.01999	0.009995	29.96	<0.001
Error	42	0.01401	0.000334		
Total	65	0.09033			

Length of the butterfly diagram during stance phase and during single support phase

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	0.001312	0.000062	10.23	<0.001
Task	2	0.000069	0.000034	5.64	0.007
Error	42	0.000257	0.000006		
Total	65	0.001637			

Anteroposterior displacement of CoP intersection point

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	0.000017	0.000001	1.26	0.256
Task	2	0.000002	0.000001	1.48	0.24
Error	42	0.000027	0.000001		
Total	65	0.000046			

Mediolateral displacement of CoP intersection point

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	0.000041	0.000002	2.64	0.004
Task	2	0.000007	0.000003	4.62	0.015
Error	42	0.000031	0.000001		
Total	65	0.000078			

The 1st peak force of average gait

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	0.103805	0.004943	4.23	<0.001
Task	2	0.008424	0.004212	3.61	0.036
Error	42	0.049067	0.001168		
Total	65	0.161296			

The 2nd peak force of average gait

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	0.046897	0.002233	8.08	<0.001
Task	2	0.008884	0.004442	16.08	<0.001
Error	42	0.011605	0.000276		
Total	65	0.067386			

Time to the 1st peak force.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	21	243.91	11.615	7.34	<0.001
Task	2	36.39	18.197	11.5	<0.001
Error	42	66.44	1.582		
Total	65	346.75			

c.2 Women

Normalized step length

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	0.06379	0.003544	5.36	<0.001
Task	2	0.02666	0.01333	20.16	<0.001
Error	36	0.02381	0.000661		
Total	56	0.11426			

Normalized step time

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	4.504	0.25022	4.86	<0.001
Task	2	2.366	1.18315	22.97	<0.001
Error	36	1.854	0.05151		
Total	56	8.725			

Stance phase

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	322.5	17.916	5.25	<0.001
Task	2	127.4	63.712	18.68	<0.001
Error	36	122.8	3.41		
Total	56	572.7			

Swing phase

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	322.5	17.916	5.25	<0.001
Task	2	127.4	63.712	18.68	<0.001
Error	36	122.8	3.41		
Total	56	572.7			

Double support phase

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	1381.1	76.73	5.66	<0.001
Task	2	540.4	270.18	19.94	<0.001
Error	36	487.8	13.55		
Total	56	2409.2			

Cadence

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	0.4397	0.024429	7.56	<0.001
Task	2	0.2844	0.142202	44.03	<0.001
Error	36	0.1163	0.00323		
Total	56	0.8404			

Velocity

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	0.11072	0.006151	8.41	<0.001
Task	2	0.07136	0.035679	48.81	<0.001
Error	36	0.02632	0.000731		
Total	56	0.20839			

Length of the butterfly diagram during stance phase and during single support phase

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	0.004327	0.00024	4.72	<0.001
Task	2	0.000658	0.000329	6.47	0.004
Error	36	0.001832	0.000051		
Total	56	0.006817			

Anteroposterior displacement of CoP intersection point

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	0.000027	0.000001	1.04	0.441
Task	2	0.000006	0.000003	1.94	0.159
Error	36	0.000051	0.000001		
Total	56	0.000083			

Mediolateral displacement of CoP intersection point

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	0.000073	0.000004	1.2	0.313
Task	2	0.000013	0.000007	1.93	0.16
Error	36	0.000122	0.000003		
Total	56	0.000208			

The 1st peak force of average gait

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	0.02652	0.001474	1.54	0.133
Task	2	0.01164	0.005822	6.08	0.005
Error	36	0.03447	0.000958		
Total	56	0.07264			

The 2nd peak force of average gait

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	0.057367	0.003187	9.65	<0.001
Task	2	0.008643	0.004322	13.08	<0.001
Error	36	0.011891	0.00033		
Total	56	0.077901			

Time to the 1st peak force.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Participant	18	390.1	21.675	6	<0.001
Task	2	120.1	60.039	16.62	<0.001
Error	36	130.1	3.614		
Total	56	640.3			

Appendix B

Full Analysis of Multiple Linear Regression Tables

a. Men

Height

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	156	30.4	5.13	<0.001	
LoS_R	0.164	0.0918	1.79	0.097	2.32
MF_F_R	-0.0213	0.0119	-1.8	0.096	1.84
MF_H_R	0.0617	0.0193	3.2	0.007	2.12
C_M_R	-0.202	0.231	-0.87	0.398	2.4

Weight

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	16.87	7.59	2.22	0.045	
T_V	-4.12	1.59	-2.59	0.022	1.85
MF_F_R	0.0649	0.0106	6.15	<0.001	2.07
MF_M_R	0.03488	0.0091	3.83	0.002	1.85
MF_H_R	0.0305	0.0149	2.05	0.062	1.81

Body mass index

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	41.29	8.62	4.79	<0.001	
T_C	-0.1089	0.0478	-2.28	0.04	1.24
LoG_R	-0.1029	0.0247	-4.17	0.001	1.45
M_F_F	0.01907	0.00322	5.93	<0.001	1.24
M_F_M	0.01635	0.0036	4.54	0.001	1.05

Total fat mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	34.3	16.2	2.12	0.056	
T_V	-3.93	2.07	-1.9	0.082	2.36
ML_SD	-0.909	0.3	-3.03	0.01	1.46
LoG_R	-0.1787	0.0699	-2.55	0.025	1.66
MF_F_R	0.04401	0.00977	4.5	0.001	1.33
MF_M_R	0.0355	0.0118	3.01	0.011	2.32

Total fat free mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-9.4	17.1	-0.55	0.596	
ML_SD	0.471	0.152	3.09	0.011	1.46
LoG_R	0.0854	0.041	2.08	0.064	2.21
LoS_R	0.1142	0.052	2.2	0.053	3.09
MF_F_R	0.00285	0.0074	0.38	0.708	2.96
MF_H_R	0.0583	0.0118	4.93	0.001	3.3
C_M_R	0.366	0.117	3.13	0.011	2.57
C_H_R	-0.4392	0.0993	-4.42	0.001	1.71

Right arm fat mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	13.19	4.15	3.18	0.008	
ML_SD	-0.0683	0.0241	-2.83	0.015	1.87
LoG_R	-0.02673	0.00489	-5.47	<0.001	1.6
MF_F_R	0.003327	0.000719	4.63	0.001	1.43
MF_M_R	0.004193	0.000604	6.94	<0.001	1.21
C_F_R	-0.1005	0.0422	-2.38	0.035	2.29

Trunk fat mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	15.83	8.88	1.78	0.1	
T_V	-2.32	1.13	-2.05	0.063	2.36
ML_SD	-0.45	0.164	-2.74	0.018	1.46
LoG_R	-0.0907	0.0383	-2.37	0.036	1.66
MF_F_R	0.02551	0.00535	4.77	<0.001	1.33
MF_M_R	0.01917	0.00645	2.97	0.012	2.32

Right leg fat mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	20.52	8.39	2.45	0.033	
T_V	-0.324	0.296	-1.09	0.298	2.73
ML_SD	-0.1171	0.0452	-2.59	0.025	1.88
LoG_R	-0.0372	0.0109	-3.4	0.006	2.29
MF_F_R	0.00639	0.00139	4.6	0.001	1.52
MF_M_R	0.00613	0.00167	3.67	0.004	2.64
C_F_R	-0.1521	0.0849	-1.79	0.101	2.65

Right arm fat free mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.886	0.911	2.07	0.059	
ML_SD	0.0557	0.0143	3.91	0.002	1.36
LOG_R	0.00798	0.00308	2.59	0.022	1.33
MF_H_R	0.003294	0.000677	4.87	<0.001	1.15
C_H_R	-0.04112	0.00758	-5.42	<0.001	1.06

Trunk fat free mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	13.08	5.29	2.47	0.028	
ML_SD	0.297	0.131	2.27	0.041	1.18
LoG_R	0.0508	0.0204	2.49	0.027	1.24
M_F_H	0.02369	0.00441	5.38	<0.001	1.71
C_H	-0.2112	0.0523	-4.04	0.001	1.34

Right leg fat free mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	4.76	1.71	2.78	0.015	
LoS_R	0.02078	0.00736	2.82	0.014	1.02
MF_H_R	0.00996	0.00163	6.1	<0.001	1.04
C_H_R	-0.0462	0.019	-2.43	0.029	1.03

b. Women

Height

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-56.2	70.2	-0.8	0.439	
AP_SD	1.339	0.499	2.68	0.02	1.69
ML_SD	-2.217	0.543	-4.09	0.002	1.75
LoG_R	0.2075	0.0947	2.19	0.049	1.24
C_F_R	1.678	0.666	2.52	0.027	1.18
C_H_R	0.432	0.133	3.25	0.007	1.08

Weight

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-1.58	9.81	-0.16	0.874	
T_V	-3.38	1.21	-2.79	0.015	1.68
MF_F_R	0.07178	0.00832	8.62	<0.001	1.66
C_M_R	0.589	0.146	4.03	0.001	1.44
C_H_R	-0.281	0.116	-2.42	0.031	1.4

Body mass index

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	20.44	5.08	4.02	0.003	
G_SRL	0.0032	0.0289	0.11	0.913	3.37
AP_SD	-0.249	0.135	-1.85	0.097	1.95
ML_SD	0.324	0.101	3.2	0.011	1.83
LoG_R	-0.0505	0.0144	-3.5	0.007	2.43
MF_F_R	0.01654	0.00278	5.96	<0.001	2.56
MF_M_R	0.01725	0.00613	2.81	0.02	2.92
C_M_R	0.1018	0.0679	1.5	0.168	4.31
C_H_R	-0.1474	0.0367	-4.02	0.003	1.93

Total fat mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	193.7	94.5	2.05	0.061	
T_V	4.49	2.06	2.18	0.048	1.67
LoS_R	-0.294	0.0707	-4.16	0.001	1.9
MF_F_R	0.0569	0.0174	3.28	0.006	3.38
C_F_R	-2.15	1.08	-1.99	0.068	4.07

Total fat free mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	18.84	7.39	2.55	0.021	
MF_F_R	0.0361	0.0123	2.93	0.01	1

Right arm fat mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.103	0.662	1.67	0.116	
LoS_R	-0.0132	0.00449	-2.94	0.01	1
MF_F_R	0.002259	0.00072	3.14	0.007	1

Trunk fat mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	97.8	44.7	2.19	0.047	
T_V	2.266	0.972	2.33	0.037	1.67
LoS_R	-0.1632	0.0335	-4.88	<0.001	1.9
MF_F_R	0.02912	0.00821	3.55	0.004	3.38
C_F_R	-1.075	0.511	-2.1	0.055	4.07

Right leg fat mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2.78	1.57	1.77	0.097	
LoS_R	-0.0292	0.0117	-2.51	0.024	1
MF_F_R	0.00493	0.00164	3.01	0.009	1

Right arm fat free mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-0.613	0.605	-1.01	0.327	
AP_SD	0.0941	0.0491	1.92	0.075	1.32
MF_F_R	0.00365	0.000884	4.13	0.001	1.32

Trunk fat free mass

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	21.94	5.44	4.03	0.001	
G_SRL	-0.1509	0.0432	-3.49	0.004	2.86
LoS_R	0.0592	0.0259	2.29	0.04	1.23
MF_F_R	0.02648	0.00481	5.51	0	2.25
C_H_R	-0.1654	0.0585	-2.83	0.014	1.5

Right leg fat free mass

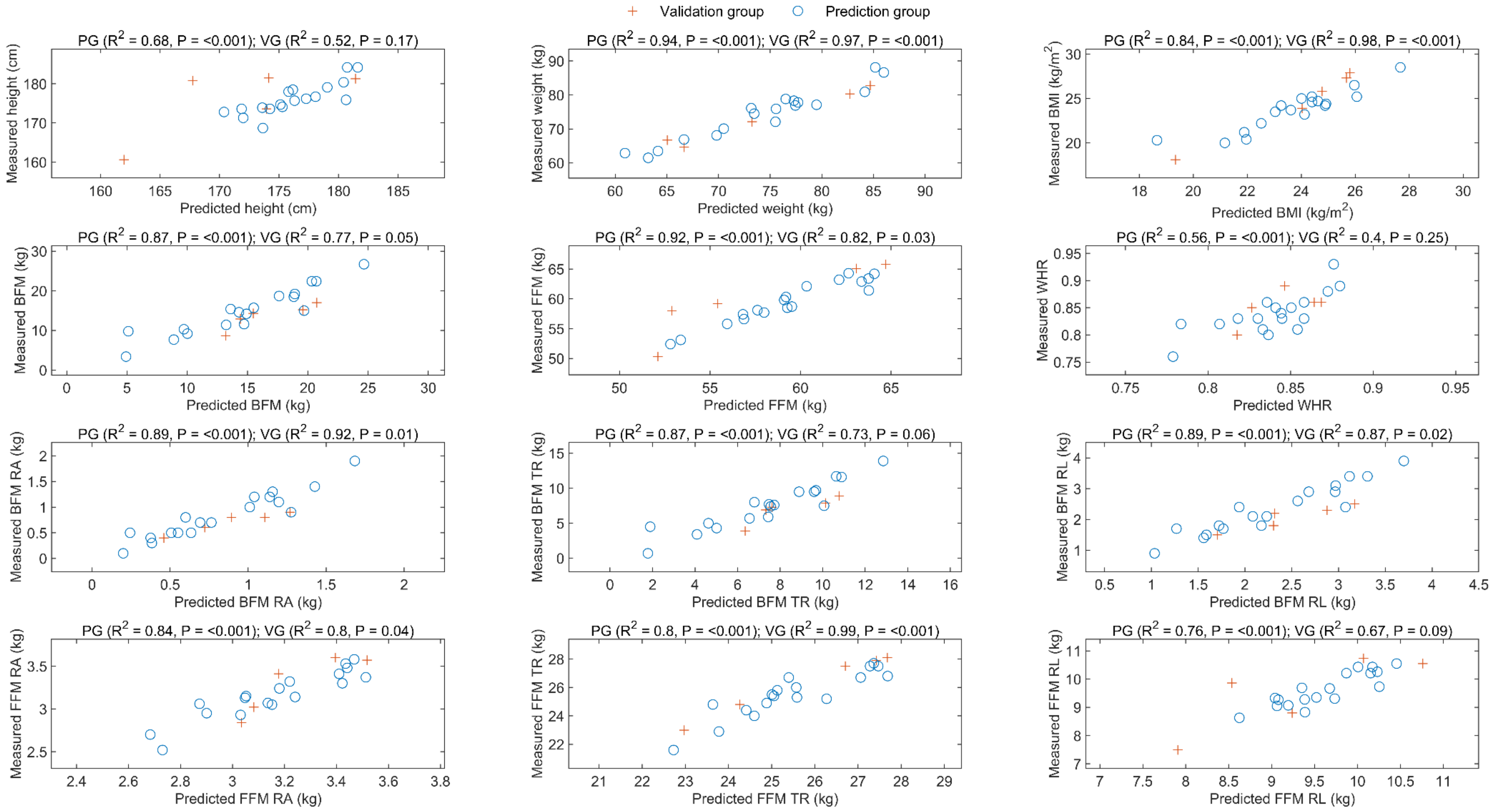
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.42	1.65	0.86	0.403	
MF_H_R	0.0128	0.00412	3.11	0.007	1

Appendix C

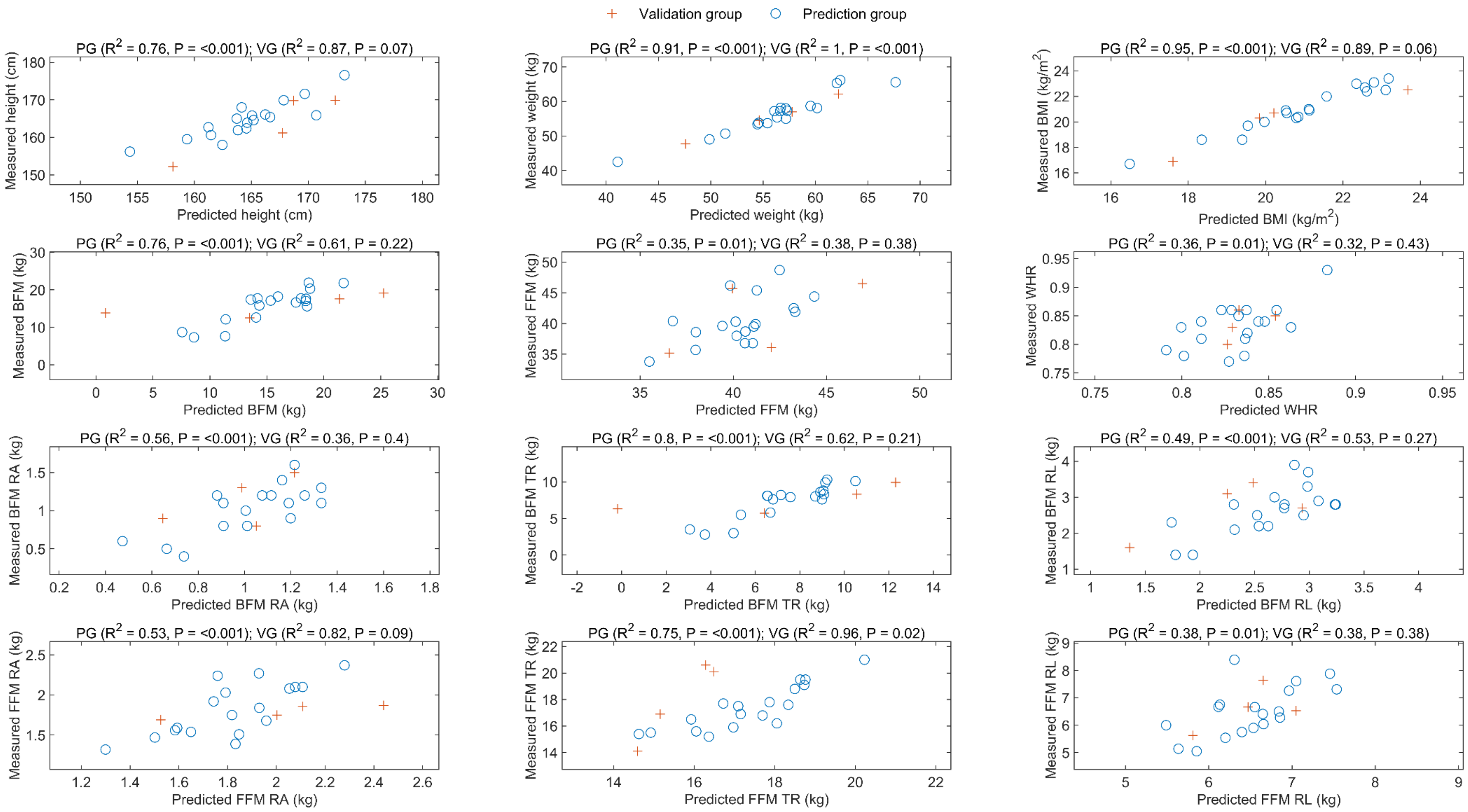
Scatter Plots of Relation Between Predicted Body Composition and Measured Body Composition

a. Scatter plots of the relation between predicted body composition and measured body composition; circles indicated prediction group (PG) and plus sign indicated the validation group (VG).

a.1 Men


Validation group
Prediction group
PG (R^2 = 0.68, P = <0.001); VG (R^2 = 0.52, P = 0.17)
Measured height (cm)
Predicted height (cm)
PG (R^2 = 0.94, P = <0.001); VG (R^2 = 0.97, P = <0.001)
Measured weight (kg)
Predicted weight (kg)
PG (R^2 = 0.84, P = <0.001); VG (R^2 = 0.98, P = <0.001)
Measured BMI (kg/m^2)
Predicted BMI (kg/m^2)
PG (R^2 = 0.87, P = <0.001); VG (R^2 = 0.77, P = 0.05)
Measured BFM (kg)
Predicted BFM (kg)
PG (R^2 = 0.92, P = <0.001); VG (R^2 = 0.82, P = 0.03)
Measured FFM (kg)
Predicted FFM (kg)
PG (R^2 = 0.56, P = <0.001); VG (R^2 = 0.4, P = 0.25)
Measured WHR
Predicted WHR
PG (R^2 = 0.89, P = <0.001); VG (R^2 = 0.92, P = 0.01)
Measured BFM RA (kg)
Predicted BFM RA (kg)
PG (R^2 = 0.87, P = <0.001); VG (R^2 = 0.73, P = 0.06)
Measured BFM TR (kg)
Predicted BFM TR (kg)
PG (R^2 = 0.89, P = <0.001); VG (R^2 = 0.87, P = 0.02)
Measured BFM RL (kg)
Predicted BFM RL (kg)
PG (R^2 = 0.84, P = <0.001); VG (R^2 = 0.8, P = 0.04)
Measured FFM RA (kg)
Predicted FFM RA (kg)
PG (R^2 = 0.8, P = <0.001); VG (R^2 = 0.99, P = <0.001)
Measured FFM TR (kg)
Predicted FFM TR (kg)
PG (R^2 = 0.76, P = <0.001); VG (R^2 = 0.67, P = 0.09)
Measured FFM RL (kg)
Predicted FFM RL (kg)

a.2 Women


+ Validation group
○ Prediction group
PG (R^2 = 0.76, P = <0.001); VG (R^2 = 0.87, P = 0.07)
Measured height (cm)
Predicted height (cm)
150
155
160
165
170
175
180
PG (R^2 = 0.91, P = <0.001); VG (R^2 = 1, P = <0.001)
Measured weight (kg)
Predicted weight (kg)
40
45
50
55
60
65
70
PG (R^2 = 0.95, P = <0.001); VG (R^2 = 0.89, P = 0.06)
Measured BMI (kg/m^2)
Predicted BMI (kg/m^2)
16
18
20
22
24
PG (R^2 = 0.76, P = <0.001); VG (R^2 = 0.61, P = 0.22)
Measured BFM (kg)
Predicted BFM (kg)
0
5
10
15
20
25
30
PG (R^2 = 0.35, P = 0.01); VG (R^2 = 0.38, P = 0.38)
Measured FFM (kg)
Predicted FFM (kg)
35
40
45
50
PG (R^2 = 0.36, P = 0.01); VG (R^2 = 0.32, P = 0.43)
Measured WHR
Predicted WHR
0.75
0.8
0.85
0.9
0.95
PG (R^2 = 0.56, P = <0.001); VG (R^2 = 0.36, P = 0.4)
Measured BFM RA (kg)
Predicted BFM RA (kg)
0.2
0.4
0.5
0.6
0.8
1
1.2
1.4
1.5
1.6
1.8
PG (R^2 = 0.8, P = <0.001); VG (R^2 = 0.62, P = 0.21)
Measured BFM TR (kg)
Predicted BFM TR (kg)
-2
0
2
4
5
6
8
10
12
14
PG (R^2 = 0.49, P = <0.001); VG (R^2 = 0.53, P = 0.27)
Measured BFM RL (kg)
Predicted BFM RL (kg)
1
1.5
2
2.5
3
3.5
4
PG (R^2 = 0.53, P = <0.001); VG (R^2 = 0.82, P = 0.09)
Measured FFM RA (kg)
Predicted FFM RA (kg)
1.2
1.4
1.5
1.6
1.8
2
2.2
2.4
2.5
2.6
PG (R^2 = 0.75, P = <0.001); VG (R^2 = 0.96, P = 0.02)
Measured FFM TR (kg)
Predicted FFM TR (kg)
14
16
18
20
22
PG (R^2 = 0.38, P = 0.01); VG (R^2 = 0.38, P = 0.38)
Measured FFM RL (kg)
Predicted FFM RL (kg)
5
6
7
8
9

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