International Journal of Advanced Science and Technology
Vol.73 (2014), pp.75-88
http://dx.doi.org/10.14257/ijast.2014.73.05

# Comparing the Kinetics of Movement while Expressing Different Emotions during the Korean Traditional Dance Movement *Gam-ki*

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***Abstract***

*The double-arm winding (Gam-ki) movement is one of the basic movements of Korean traditional dance. Using lapsed time studies, ratio, relative time point of completing joint movement, size of movement, and the difference between ground reaction forces and ground impulse analysis, we investigated the characteristics of movement depending on the emotion being expressed. We selected 11 Korean traditional dancers with more than 10 years of experience (age: 26 ± 1.5 years, height: 167.6 ± 6.4 cm, weight: 53.6 ± 6.8 kg), portraying 4 different emotions (anger, joy, sadness, and neutral). The results of repeated measurements were statistically analyzed through one-way ANOVA. Unlike movements in sports, the Gam-ki movement follows the order of hip, knee, and ankle joints during the weight-acceptance phase. The hip joint movement quickened when a relatively active emotion ("angry" or "joy") was expressed. The movement was transmitted to the distal joints relatively slowly when "joy" or "sadness" emotion was expressed as opposed to when "neutral" or "angry" emotions were displayed. Unlike the arm joints, the movement range of the leg joints is largely influenced by body movement; hence, it was difficult to consider it as an emotional characteristic.*

***Keywords:*** *Korean traditional dance, winding arms, emotion, bodily expression, kinematics*

## 1. Introduction

We often perceive the emotions of a person through his or her movements. This indicates that the body movements relay emotional characteristic factors that can be visually identified. Therefore, several studies have been conducted to identify emotional characteristic factors in routine movements such as walking. Wallbott [1] studied body movements while expressing 16 emotions and found that, while movement or posture characteristics related to the emotions seem to exist, the difference in movement between emotions can be partially explained by the activity range. Movements are faster, larger, and expanded for joy or anger, and are slower and smaller when satisfaction or sadness is expressed [1–5]. Gross [2] reported that although larger movements of the hip, shoulder, elbow, pelvis, and torso during "anger" or "joy" as compared to that during "sadness" can be explained by the speed of walking, the neck and chest flexion during "sadness", and body extension and shoulder drop during "joy" were not related to the speed of walking.

ISSN: 2005-4238 IJAST

Dance is an art form that involves expression of emotions through bodily movements. Studies on the expression and recognition of emotions through dancing movements [6-9] focused on the duration of the movements, changes in the beat, length of the pause between changes, body expansion, and movement dynamics while expressing emotions such as anger, fear, sadness, or joy. However, most were qualitative studies on self-selected movements or series of movements, and only a few were quantitative studies. Moreover, there has been little effort made to identify the emotional characteristic factors that appear in each unit of movement or detailed phases through quantitative movement analysis. Few studies have been reported on walking [2], knocking [10], or drinking motion [11] with virtually none on the emotion-dependent kinematic or kinetic characteristics of dance movements.

Although there are many commonalities in communication via facial expression and gestures, several differences exist as per nation or culture. Therefore, it is easy to predict that the characteristics of dance movements would be different between cultures. Among related cultures such as Korea, China, and Japan, which have long been exchanging cultures due to close geographical proximity and by virtue of being located in the same oriental culture zone, the visible characteristics of traditional dance movements in these regions vary. Therefore it would be unreasonable that the results from previous study on the expression characteristics of dance movements are applied to Korean traditional dance movements.

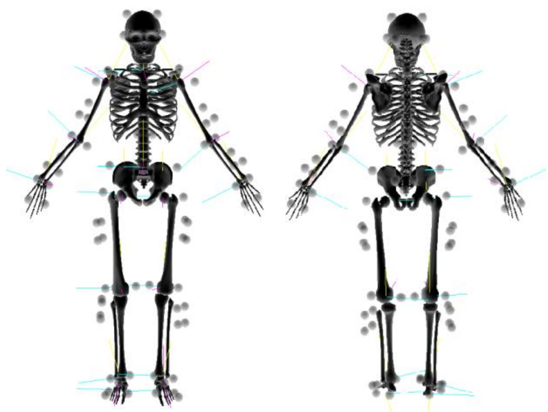

**Figure 1. Anatomical Location of Reflective Markers**

Therefore, we studied movement characteristics dependent on the emotion being expressed (anger, joy, sadness, and neutral) by using analyses of the spatiotemporal and kinetic variables (the elapsed time, the relative time for completion of joint movement, the volume of movement and the ground reaction forces and ground impulses during Gam-ki (winding) motion, which is one of the basic motions in Korean traditional dance. This study is expected to contribute to the development of a computer program to evaluate emotions expressed in motion or to synthesize motion with emotion.

## 2. Study Methods

### 2.1. Study Subjects

This study was conducted after approval from the institutional review board of Sangmyung University. A total of 11 female, Korean traditional dancers (age: 26 ± 1.5 years, height: 167.6 ± 6.4 cm, weight: 53.6 ± 6.8 kg) without neuro-orthopedic disease and with more than 10 years of experience in stage performance, residing in the Seoul or Gyeonggi areas of Korea were selected. They performed a traditional Korean dance movement, the double-hand *Gam-ki* (winding).

 

While performing the *Gam-ki*, one of the most basic movements in Korean traditional dance, both legs are bent alternatively in a winding motion. During this movement, the leg joint on one side is bent to accept the weight and the two arms are wind the trunk. Next, to transfer the weight to the opposite leg, the leg joint is extended with the opening of the arms. While transferring the weight from left to the right, the arms are closed and opened repeatedly. Twisting of the upper body from left to right alternatively is added at this point, so the right arm moves forward with the left arm backwards. This movement is repeated in reverse.

### 2.2. Experimental Tools and Procedure

Three-dimensional movement analysis was performed for this study. Motion data was collected using 11 infrared cameras (Qualisys, Oqus 3-series motion capture system, SF: 200 frame/sec) and two force plates (Kislter, Type 9286A, SF: 1000 Hz) were used to measure ground reaction force.

The movements were performed while wearing an open-back shoulder-strap style top and a short-pants style leotard. To calculate the kinematic data, the body was defined as a rigid body composed of 15 segments, and spherical reflective markers (15 mm in diameter) were attached to the subject's body to calculate the location of each segment (Figure 1).

Before the experiment, the subjects were asked to write their own experiences or hypothetical situations that could remind them of the 3 emotions (anger, joy, and sadness). After the explanation of the double-arm winding movement, they were asked to express the requested emotion using their own notes, and they performed the movement with no instruction on the expression methods of the movements. Only those subjects whose movements were considered satisfactory after the performance were selected for analysis.

### 2.3. Analysis Methods and Data Processing

**2.3.1. Events and Phases:** Events and phases were classified as shown in Figure 2 and the detailed definitions are as follows.

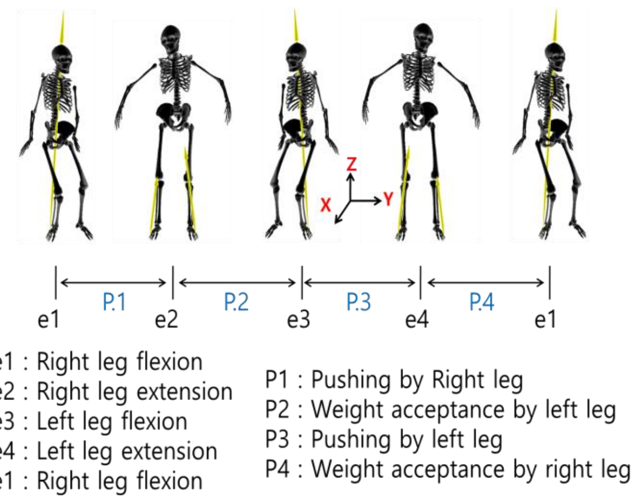


**Figure 2. Events and Phases**

Event 1: The time point when the right ankle joint reaches maximal dorsi flexion.

Event 2: The time point when the right ankle joint reaches maximal plantar flexion.

Event 3: The time point when the left ankle joint reaches maximal dorsi flexion.

Event 4: The time point when the left ankle joint reaches maximal plantar flexion.

Phase 1: The phase in which the center of gravity is moved upward by pushing the ground with the right leg (e1 to e2).

Phase 2: The phase in which the left leg accepts the body weight (e2 to e3).

Phase 3: The phase in which the center of gravity is moved upward by pushing the ground with the right leg (e3 to e4).

Phase 4: The phase in which the right leg accepts the body weight (e4 to e1).

**2.3.2. Data Processing and Statistical Analyses:** Video data was processed using Visual 3D (C-Motion Inc., USA) biomechanics software. To remove noise from motion data and ground reaction force data, fourth-order, low-pass Butterworth digital filter was used with the cut-off frequency set at 6 Hz. SPSS 17.0 (SPSS Inc., USA) was used for statistical analysis, with the significance level at $a$ = .05.

## 3. Analysis Variables

### 3.1. Time Elapsed in Each Phase

To investigate the speed of double-arm winding motion as well as the speed during each phase depending on the emotion expressed, the ratio of time elapsed in each phase was calculated by normalizing the time elapsed in the left-foot weight-acceptance phase (P2) and propulsion phase (P3) to the time elapsed in 1 cycle of double-arm winding movement.

### 3.2. Time Points for the Maximal and Minimal Joint Angle

The relative time point for the maximal flexion and maximal extension were calculated as the time point when the flexion and the extension movements of the ankle, knee, hip, elbow, and wrist joints (adduction and abduction of the shoulder joints) were complete, which means that the time elapsed after event 1 (or event 3) was normalized by one full cycle of the double-arm winding movement. This was to compare the Joint rhythms depending on the emotion expressed, through the phase delay of the body joint angle.

### 3.3. Range of Motion (ROM)

ROM of the body joints was calculated to identify the difference in the size of movement, depending on the expressed emotion.

### 3.4. Ground Reaction Force and Ground Impulse

During the double-arm winding the weight moves not only up-down but also left-right by bending both legs alternately. Therefore, to quantify the weight-shifting pattern dependent on the emotion expressed, the vertical and lateral components of ground reaction force and ground impulse (change in momentum) were calculated.

### 3.5. Asymmetric Index (ASI) of the Weight-acceptance and Propulsion Phases

During double-arm winding movement, the leg joint is flexed to accept the body weight and undergoes an eccentric contraction, after which the leg joint is extended to shift the weight to the opposite leg. Concentric muscle contraction takes place at this point. Therefore, we quantified the elapsed time and the asymmetry level of ground reaction force during the weight-acceptance phase (P2), in which an eccentric contraction occurs and the propulsion phage (P3), in which concentric muscle contraction takes place. ASI is the difference in the average values of P2 and P3; when the ASI value is 0, phases are considered symmetric, whereas a positive value denotes a large P3 and a negative value, a larger P2.

$$ASI_M = \frac{2(M_{P3} - M_{P2})}{M_{P3} + M_{P2}}$$

Range: $-2 < ASI < 2$
$M_{P2}$: variables (elapsed time or mean GRF) during P2
$M_{P3}$: variables (elapsed time or mean GRF) during P3

## 4. Results

From here on, “angry” is denoted as A, “joy” as J, “sadness” as S, and “neutral” as N for simplicity.

### 4.1. Elapsed Time for Each Phase

Table 1 Elapsed time and % normalized time for each cycle.

| | phase | emotions: angry | joy | neutral | sadness | *p* | N-A | N-J | N-S | A-J | A-S | J-S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | P2 | 24.4±1.7 | 25.0±0.9 | 24.9±1.5 | 23.6±4.9 | .532 | .366 | .853 | .415 | .363 | .643 | .313 |
| | P3 | 25.3±2.2 | 25.1±1.4 | 24.8±1.5 | 26.6±5.2 | .707 | .332 | .650 | .289 | .771 | .398 | .375 |
| | ASI | 3.7±15.5 | 0.4±7.0 | -0.1±11.4 | 12.1±40.0 | .682 | .340 | .898 | .348 | .491 | .515 | .344 |
| ms | P | 2604±874 | 2653±843 | 3320±926 | 6924±2860 | **.003** | **.001** | **.012** | **.003** | .837 | **.001** | **.001** |
| | P2 | 635±219 | 663±211 | 830±250 | 1612±692 | **.003** | **.000** | **.017** | **.003** | .618 | **.001** | **.002** |
| | P3 | 653±203 | 662±198 | 817±202 | 1854±952 | **.009** | **.002** | **.013** | **.006** | .871 | **.003** | **.002** |

The elapsed time for each phase and normalized elapsed time dependent on the emotion expressed are shown in Table 1. The elapsed time appeared in the order of S > N > J > A, not only in 1 cycle of double-arm winding movement (P), but also in the left-foot weight-acceptance phase (P2) and propulsion phase (P3). However, J > A was seen as statistically insignificant ($p$ = .837, .618, .871 for S, N, J, and A, respectively). In addition, the elapsed time ratio per phase, normalized to the time elapsed during 1 cycle of movement appeared in the order of J > N > A > S in the left-foot weight-acceptance phase (P2), but was seen as statistically insignificant ($p$ = .532). It appeared in the order of S > A > J > N in the propulsion phase (P3) but was seen as statistically insignificant ($p$ =.707). ASI for P2 and P3 was highest in S, followed by other emotions in the order A, J, and N, but was statistically insignificant.

### 4.2. Relative Time Point when Joint Flexion/Extension was Complete

The relative time points when joint flexion or extension (adduction or abduction of shoulder joints) was complete, were normalized to the relative time (time%) with the time point e3 as the standard, which is when the left ankle joint flexion was complete (Figure 3, Table 2). The horizontal axis in Figure 3 denotes the body joints (in the order of the joints closest to the ground) and the vertical axis, the relative time. The relative time point (h3) of the hip joint flexion completion was fastest in A and J followed by N and S, depending on the emotion expressed, but was statistically insignificant ($p$ = .057). The relative time point (h4) of hip joint extension completion was faster in A and J than N. Furthermore, there was no significant difference between the relative time point of flexion completion in the ankle, knee, and shoulder joints and the relative time point of extension completion of these joints. While the relative time point of extension completion appeared in the order of (A, N) < (J, S), N < J ($p$ = .072) was statistically non-significant. The relative time point of flexion completion of the wrist joint was (N, A, J) < S, with no significant difference. The relative time point of extension completion for A and N was earlier than J and S. However, N < J ($p$ = .123) was statistically insignificant.

In the time points (e3, k3, h3, s3, L3, and w3) when flexion (adduction for the shoulder joint) of the joints was complete, the order of flexion was hip, knee, and ankle joint, while expressing A, J, and N, but no significant difference was seen for S. For arm joints, the flexion order was shoulder, elbow, and wrist joint for all emotions in the order mentioned. In addition, adduction of the shoulder joints was completed after flexion of the hip joint for all emotions, but it was statistically insignificant for N ($p$ = .157). For the time points (e4, k4, h4, s4, L4, and w4) of joint extension completion (abduction for the shoulder joint), the order for the leg joints was hip, knee, and ankle joint, the order for the arm joints was shoulder, elbow, and wrist joint, for all emotions expressed. Moreover, the abduction of the shoulder joints was completed after extension of the hip joint for all emotions but it was statistically insignificant for N ($p$ = .082).

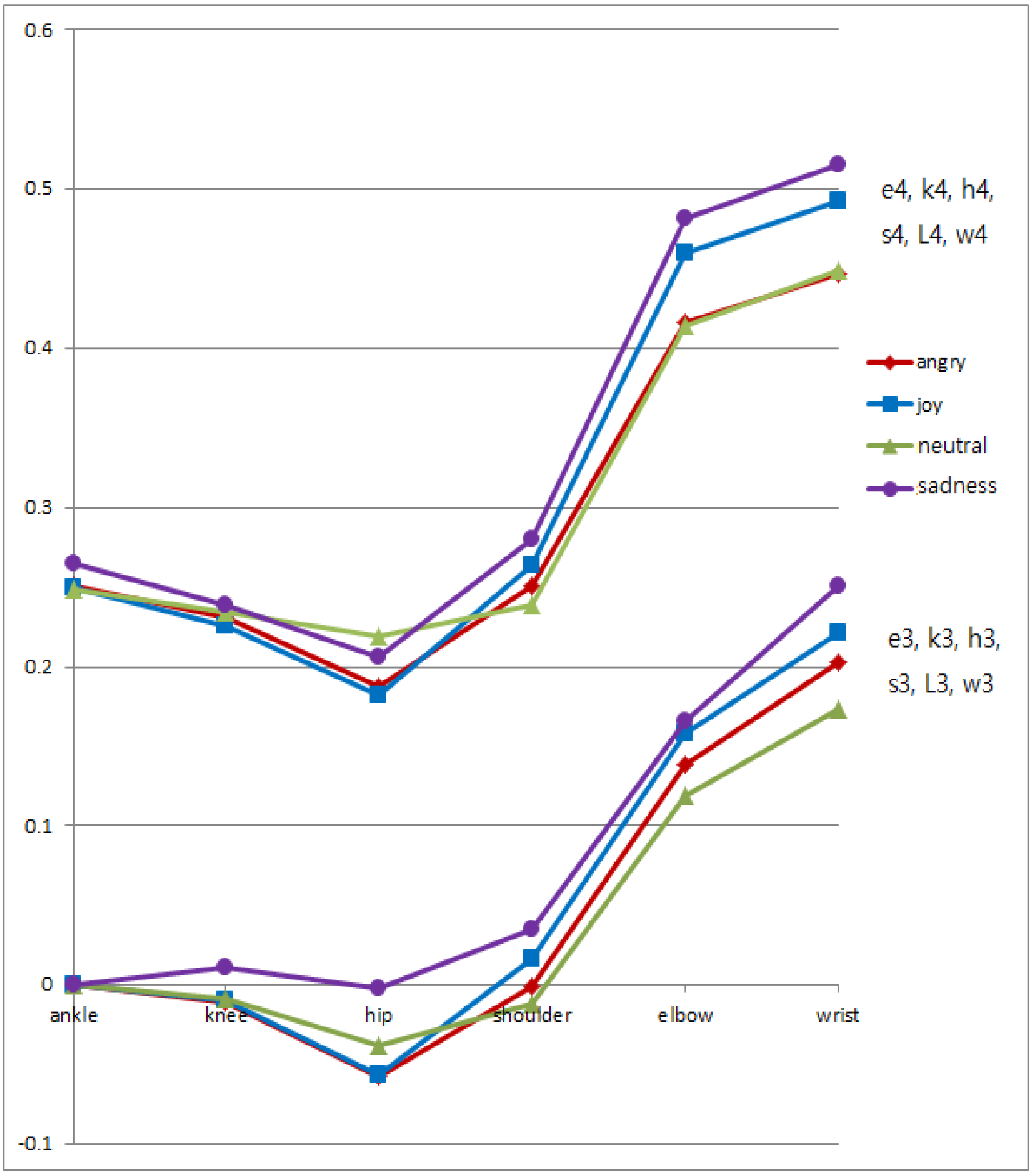


**Figure 3. Relative Time Point when Joint Flexion or Extension (Adduction/Abduction of Shoulder Joints) was Complete**

Table 2. Relative Time Point when Joint Flexion or Extension (Adduction/Abduction of Shoulder Joints) was Complete during the Left-foot Weight-acceptance Phase (P2) and Propulsion Phase (P3) (time %).

 

| | | | emotions | | | | *p* | *p* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | angry | joy | neutral | sadness | | N-A | N-J | N-S | A-J | A-S | J-S |
| ankle | e3 | L max. flex. | 0±0 | 0±0 | 0±0 | 0±0 | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| | e4 | L max. ext. | 25.0±2.4 | 24.9±1.6 | 24.8±1.5 | 26.5±5.2 | .819 | .649 | .896 | .318 | .856 | .362 | .360 |
| knee | k3 | L max. flex. | -1.1±0.8 | -0.9±0.5 | -0.9±0.6 | 1.1±4.1 | .464 | .552 | .599 | .112 | .661 | .094 | .106 |
| | k4 | L max. ext. | 23.1±1.6 | 22.6±1.4 | 23.5±1.2 | 23.9±6.0 | .372 | .213 | .123 | .827 | .387 | .630 | .496 |
| hip | h3 | L max. flex. | -5.7±4.1 | -5.6±3.3 | -3.8±2.0 | -0.2±6.8 | .057 | .138 | .038 | .091 | .889 | .022 | .014 |
| | h4 | L max. ext. | 18.7±4.7 | 18.2±2.8 | 21.9±1.5 | 20.6±6.3 | **.043** | **.033** | **.000** | .467 | .670 | .228 | .194 |
| shoulder | s3 | R max. add. | -0.1±6.9 | 1.7±3.8 | -1.2±5.0 | 3.5±6.8 | .106 | .649 | .045 | .067 | .315 | .082 | .226 |
| | s4 | R max. abd. | 25.1±7.7 | 26.4±3.1 | 23.8±3.7 | 28.0±6.5 | .141 | .599 | .041 | .043 | .538 | .149 | .278 |
| elbow | L3 | R max. flex. | 13.8±10.1 | 15.8±5.2 | 11.8±6.6 | 16.6±8.6 | .094 | .612 | .035 | .083 | .474 | .277 | .638 |
| | L4 | R max. ext. | 41.6±6.8 | 46.0±4.1 | 41.5±7.2 | 48.2±7.7 | **.011** | .952 | .072 | **.039** | **.029** | **.005** | .134 |
| wrist | w3 | R max. flex. | 20.3±10.7 | 22.2±6.1 | 17.4±8.1 | 25.1±8.4 | **.040** | .516 | .075 | **.024** | .435 | .067 | **.038** |
| | w4 | R max. ext. | 44.7±7.9 | 49.3±5.3 | 44.9±9.4 | 51.5±7.5 | **.049** | .956 | .123 | **.039** | **.039** | **.009** | .066 |

| | | *p* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | angry | | joy | | neutral | | sadness | |
| | | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 |
| *p* | | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| ankle | knee | **.001** | **.003** | **.000** | **.000** | **.001** | **.000** | .370 | **.000** |
| | hip | **.001** | **.009** | **.000** | **.000** | **.000** | **.000** | .938 | **.000** |
| | shoulder | .970 | .979 | .176 | .137 | .433 | .443 | .115 | .237 |
| | elbow | **.001** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| | wrist | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| knee | hip | **.003** | **.014** | **.001** | **.000** | **.001** | **.005** | .280 | **.001** |
| | shoulder | .665 | .428 | **.042** | **.003** | .819 | .788 | .061 | **.004** |
| | elbow | **.001** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| | wrist | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| hip | shoulder | **.042** | **.029** | **.001** | **.000** | .157 | .082 | **.029** | **.000** |
| | elbow | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| | wrist | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| shoulder | elbow | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| | wrist | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** |
| elbow | wrist | **.000** | .059 | **.000** | **.004** | **.000** | .098 | **.000** | **.004** |

3 : e3, k3, h3, s3, L3 or w3
4 : e4, k4, h4, s4, L4 or w4

### 4.3. ROM of the Joints

Table 3 ROM of the Joints (the left arm for the upper limb, right leg for the lower limb)

| | | emotions | | | | *p* | *p* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | angry | joy | neutral | sadness | | N-A | N-J | N-S | A-J | A-S | J-S |
| Neck | flexion | 17.9±20.1 | 9.2±4.3 | 5.5±2.1 | 17±14.3 | .089 | .067 | .011 | .028 | .166 | .887 | .078 |
| | lateral flex. | 18.7±8.7 | 21.7±8.1 | 7.8±5.3 | 21.7±11 | **.000** | **.003** | **.000** | **.001** | .327 | .306 | .984 |
| | rotation | 26.1±14.2 | 19.6±9.6 | 10.6±6.3 | 25.6±18.7 | **.001** | **.001** | **.001** | **.007** | .113 | .909 | .224 |
| waist | flexion | 16.2±12.7 | 13.5±5.3 | 10.8±4.6 | 15.9±7.6 | **.025** | .126 | **.026** | **.026** | .478 | .937 | .263 |
| | lateral flex. | 12±7.2 | 9.6±3.9 | 6.3±2.6 | 9.2±5.7 | **.012** | **.017** | **.007** | .118 | .176 | .089 | .687 |
| | rotation | 19.1±9.1 | 15.2±7.1 | 11.7±3.4 | 15.3±5.7 | **.016** | **.004** | .083 | **.020** | .179 | .200 | .976 |
| L_ankle | flexion | 24.2±8.3 | 25.3±6.7 | 21.5±8.2 | 27.5±9.1 | .100 | .138 | .125 | .033 | .507 | .167 | .075 |
| | abduction | 8.9±6.5 | 9.9±4.1 | 5.4±3 | 9.4±6.5 | **.009** | **.041** | **.000** | **.011** | .557 | .727 | .676 |
| | inversion | 10.6±5.8 | 11±3.7 | 10±3.9 | 13.3±2.3 | .106 | .736 | .385 | .006 | .792 | .161 | .015 |
| L_knee | extension | 36.8±16 | 35.6±11 | 33.4±13.6 | 39.2±13.3 | .275 | .266 | .629 | .242 | .812 | .643 | .067 |
| | abduction | 6.7±4.7 | 8.8±2.9 | 6.7±3.9 | 9±3.4 | **.030** | .994 | **.009** | **.010** | .131 | .062 | .757 |
| | rotation | 9.5±4.8 | 8.5±6.2 | 5.5±3.9 | 7.2±5.8 | **.025** | **.011** | .074 | .167 | .519 | .125 | .090 |
| L_hip | extension | 10.4±10.4 | 8.7±3.1 | 8.8±3.8 | 11.2±5.2 | .419 | .559 | .892 | .286 | .611 | .829 | .100 |
| | abduction | 2.4±1.2 | 2±.9 | 3.2±2.4 | 3.1±1.7 | .272 | .427 | .131 | .871 | .261 | .376 | .050 |
| | rotation | 5.6±5.4 | 5.3±3 | 2.6±1.7 | 4±3.1 | **.028** | .103 | **.004** | **.024** | .833 | .353 | .169 |
| R_shlder | flexion | 17.2±7.5 | 18.9±15.3 | 12.1±5.1 | 12.9±4.6 | .209 | .105 | .159 | .679 | .775 | .096 | .297 |
| | abduction | 63.7±16.8 | 62.8±11.9 | 53±10 | 59±8.4 | **.036** | **.012** | **.030** | **.039** | .873 | .244 | .302 |
| | rotation | 19±15.9 | 12.8±7.9 | 17.4±13.1 | 8.6±5.9 | .112 | .769 | .300 | .074 | .229 | .071 | .149 |
| R_elbow | flexion | 72.6±10.8 | 73±11.8 | 66.6±14.7 | 63.5±14.6 | .071 | .243 | .157 | .422 | .906 | .066 | .023 |
| | abduction | 36.6±9.2 | 37.5±8.7 | 34.1±9.8 | 38±8.7 | **.037** | .108 | .067 | **.030** | .298 | .331 | .694 |
| | rotation | 19.9±12.1 | 18.1±9.8 | 21±10.2 | 16.8±11.3 | .690 | .575 | .205 | .380 | .469 | .535 | .719 |
| R_wrist | flexion | 51.5±12.5 | 49.3±9.3 | 41.4±12.8 | 46.8±11.7 | **.033** | **.032** | **.022** | .206 | .483 | .178 | .391 |

Table 3 shows ROM during the left-foot weight-acceptance phase (P2) and propulsion phase (P3). The flexion/extension angle ROM of the neck joint was in the order of (A, S) > J > N, which was statistically insignificant ($p$ = .089). The lateral flexion angle ROM was in the order of (J, S) > A > N, and only (A, J, S) > N was statistically significant. The lateral rotation angle ROM was in the order of (A, S) > J > N, and only (A, J, S) > N was statistically significant. The flexion/extension angle ROM and rotation angle ROM was larger when negative emotions (A, S) were expressed, but the lateral flexion angle ROM appeared larger when either negative or positive emotions were expressed.

The flexion/extension angle ROM of the waist joint was in the order of (A, S) > J > N, only (J, S) > N was statistically significant. The lateral flexion angle ROM was in the order of A > (J, S) > N, but only (A, J) > N was statistically significant. The lateral rotation angle ROM was in the order of A > (J, S) > N, but only (A, S) > N was statistically significant.

In case of the ankle joint, the flexion/extension angle ROM was in the order of S > (A, J) > N, but it was statistically insignificant ($p$ = .100). The adduction/abduction angle ROM was in the order of (J, S, A) > N, and there was no difference in the external/internal rotation angle ROM. In case of the knee joint, the flexion/extension angle ROM was in the order of (S, J) >

 

(A, N), but only (S, J) > N was statistically significant. The external/internal rotation angle ROM of the hip joint was larger for J and S than for N. In case of the shoulder joint, the flexion/extension angle ROM was in the order of (J, A) > (S, N), but it was statistically insignificant ($p$ = .209). The adduction/abduction angle ROM for A, J, and S was larger than that for N. The flexion/extension angle ROM of the elbow joint was in the order of (J, A) > (N, S), but it was statistically insignificant ($p$ = .071); the adduction/abduction angle ROM was in the order of (S, J) > A > N, but only S > N was statistically significant. The flexion/extension angle ROM of the wrist joint was in the order of A > J > S > N, only (A, J) > N was statistically significant.

### 4.4. Ground Reaction Force and Ground Impulse

Table 4 Average Ground Reaction Force (%BW) and Ground Impulse for Each Phase (%BW·s)

| | | | emotions | | | | $p$ | $p$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | angry | joy | neutral | sadness | | N-A | N-J | N-S | A-J | A-S | J-S |
| L_GRF | medial | P2 | 7.8±4 | 6.4±2 | 5.2±1.7 | 3.2±1.8 | **.014** | .053 | **.023** | **.005** | .148 | **.004** | **.001** |
| | | P3 | 8±3.3 | 6.5±1.7 | 5.5±1.4 | 3.8±1.5 | **.013** | **.017** | **.009** | **.006** | .092 | **.002** | **.001** |
| | vertical | P2 | 81.8±18 | 89.4±6.4 | 80.5±8.2 | 83.1±6.5 | **.004** | .840 | **.000** | .264 | .255 | .843 | **.008** |
| | | P3 | 72±11.7 | 75.2±8.3 | 73.9±8.8 | 69.1±7.8 | .098 | .420 | .557 | .040 | .411 | .426 | .015 |
| L_foot_imp | medial | P2 | 4.7±3.1 | 3.9±0.9 | 4.1±1.1 | 4.3±2.4 | .693 | .540 | .521 | .756 | .446 | .733 | .585 |
| | | P3 | 4.9±2.3 | 4.1±0.8 | 4.3±0.8 | 6.5±2.8 | .089 | .376 | .271 | .012 | .276 | .173 | .011 |
| | vertical | P2 | 51.9±21.1 | 58.5±15.5 | 66.7±22.5 | 135.4±64.2 | **.037** | **.046** | .175 | **.003** | .302 | **.002** | **.003** |
| | | P3 | 45.2±8.6 | 48.5±9.6 | 59.4±11.5 | 128.9±72.1 | **.005** | **.001** | **.005** | **.011** | .182 | **.004** | **.004** |

Table 4 shows the horizontal and vertical components of the average ground reaction force and ground impulse for the left-foot weight-acceptance phase (P2) and propulsion phase (P3). The horizontal component of the average ground reaction force was in the order of A > J > N > S for both P2 and P3; A > J ($p$ = .148) and A > N ($p$ = .053) in P2 and A > J ($p$ = .092) in P3 were statistically insignificant. The vertical component in P2 was in the order of J > S > A > N, but only J > S 와 J > N was statistically significant, whereas it was in the order of J > N > A > S in P3, but was statistically insignificant ($p$ = .098).

In the integral value of ground impulse for each phase, which is the impulse received on the left foot from the ground, while there was no difference in the horizontal component during P2, it was in the order of S > A > N > J during P3, which was statistically insignificant ($p$ = .098). The vertical component in both P2 and P3 appeared in the order of S > N > J > A, but N > J ($p$ = .175) and A > J ($p$ = .302) in P2 and A > J ($p$ = .182) in P3 were statistically non-significant.

## 5. Discussion

In this study, we analyzed the elapsed time, movement size, ground reaction force, and ground impulse dependent on the emotion expressed while performing the double-arm winding (*Gam-ki*) movement of Korean traditional dance to identify differences between emotions.

The time elapsed while performing the complete double-arm winding movement as well as that for each phase was shorter when trying to express A and J as compared to N, and slowest when trying to express S. This is consistent with the results from a previous study [2, 3] on dance movements including walking. However, there was no significant difference in the elapsed time for P2 and p3 depending on the emotion expressed, which was normalized to the elapsed time of 1 cycle movement. As ASI of P2 and P3 lapsed time was statistically non-significant, there was no significant difference in the speed during each phase, although the overall movement was faster depending on the emotion expressed. ASI of P2 and P3 elapsed time was higher when S was expressed than when other emotions were expressed, though the difference in ASI between emotions was statistically non-significant. This indicates that the elapsed time in P2 was shorter than that in P3 when S was expressed as compared to that when other emotions were expressed. Furthermore, a previous study on 'knock' movement [10] showed a possibility of a potential emotion-dependent difference in the hand-raising phase (concentric contraction) and the hand-lowering phase (eccentric contraction), although it did not provide a statistical significance due to the small analysis size. Therefore, more attention is needed in the emotion-dependent elapsed time for each phase in the future.

We investigated the time point when flexion and extension of each joint (adduction and abduction for the shoulder joint) was complete, which can indicate the order of the body joint movement depending on the emotion expressed and also the relative time point. As a result, when trying to express N after A and J, the relative time to complete the hip joint flexion was shorter but the statistical significance decreased in the relatively distal joints including the knee ($p$ = .372) and the ankle joint ($p$ = 819). This suggests that the hip joint (proximal) than the ankle or knee joint (distal) is more involved in the expression of A and J. The result that the speed is higher and ROM is larger when A or J is expressed, suggests that they are more active emotions than S or N and movement of the proximal joints, especially the hip joint, is completed relatively quicker when trying to express these active emotions.

In addition, the time point when flexion/extension (adduction/abduction for the shoulder joint) of the body joints was complete (Table 2 and Figure 3) showed that movement is initiated in the hip joint and spreads to the arm and leg joints. In the arm joint, the time elapsed for transmission from the pelvis to the wrist is more than 25% of the time elapsed for the complete cycle once. In the leg joints the time elapsed in transmitting from the pelvis to the ankle is only about 6%; it appears especially short for S. In movements, similar to the one in the weight-acceptance phase in this study such as landing after jumping or squat movement in sports, movements of the leg joints are completed at nearly the same time or the movement is transmitted from the distal joint to proximal joint in general. [12]. Thus, a unique finding of this study is that the weight-acceptance phase movement is first completed in the proximal joints.

In addition, the relative time point to complete extension of the elbow or wrist joint is slower when trying to express N or A than J or S. This indicates that movement is more slowly transmitted to the neighboring joint as if the body were an extended whip. This characteristic cannot be identified in the factors that previous studies focused on (i.e., activation, volume of motion, dynamics, expansion, stability, etc.). The reason is that the movement speed and the movement volume can be independent on the relative time point for the maximal joint flexion/extension. Therefore, because the relative completion time point of flexion or extension of a joint can represent the phase delay of the body joints quantitatively, it can be a tool to quantify the emotional characteristics of body movements, which cannot be identified using existing variables.

In a kinematic study on walking dependent on emotions [1], flexion/extension ROM of the hip, knee, and ankle joint was found to be smallest when trying to express S (only the hip joint was statistically significant). However, in this study the flexion/extension ROM of the hip, knee, and ankle joint was largest when trying to express S. In case of walking movement, the gait length and speed increased as joint ROM increased due to the movement characteristic of continuously moving forward, which seems to be prevented by decreasing the joint ROM. However, because the movement direction in the double-arm winding (*Gam-ki*) movement has to be shifted from left to right repeatedly, the movement speed does not increase even if the leg joint ROM is increased. The reason for this is that if an increased leg joint ROM is used for a vertical but not horizontal movement, it does not increase movement speed, but rather extends the elapsed time of the movement due to the projectile principle. Therefore, it is difficult to consider the leg joint ROM as an emotion characteristic factor as it is strongly affected by body movement. On the other hand, in case of the arm joints (shoulder, elbow, wrist), the result of (A, J) > S > N, was similar to the previous study results and thus, the arm joint ROM appears to be one of the emotional characteristic factors. In addition, in case of the neck and waist joint, the lateral rotation angle ROM was (A, S) > N, suggesting that the lateral rotation movement is used to express negative emotions. This is consistent with the fact that lateral rotation movement is used while expressing negative gestures in general.

While the average lateral ground reaction force for both P2 and P3 was in the order of A > J > N > S, there was no difference in the lateral ground impulse (the integral value of ground reaction force). In other words, when expressing A and J, the greater force is applied to push the ground laterally, because the movement direction must be converted relatively fast and the movement is larger. On the other hand, when expressing S and N the smaller force is applied to push the ground laterally, because the direction is converted slower and so the elapsed time is longer. It is considered that because the elongated time compensated the smaller force, there was no difference in the lateral ground impulse. Additionally, as the vertical components are unrelated to the speed of direction conversion and the elapsed time, in addition to the added effect of gravity, the longer the elapsed time, the larger the average vertical ground impulse seemed to be.

## 6. Conclusion

In this study, we analyzed the elapsed time, movement size, ground reaction force, and ground impulse depending on the emotion expressed while performing the double-arm winding (*Gam-ki*) movement of Korean traditional dance and identified differences between emotions. A summary of the results is as follows:

1. Unlike movements in sports, movement during the eccentric contraction phase (weight-acceptance phase) is in the order of a hip, a knee, and an ankle joint. While trying to express relatively active emotions such as “angry” or “joy”, movement of the proximal joint, especially the hip, is quicker.
2. By investigating the relative time point when each body joint movement was complete, we found that the movement is transmitted to the distal joints more slowly like an elongated whip, when trying to express “joy” or “sadness” rather than when trying to express “neutral” or “angry”.
3. Unlike the arm joints, it is difficult to consider the leg joint ROM as a characteristic factor for emotions as it is strongly influenced by body movement.

## Acknowledgements

This research was supported by the Ministry of Science, ICT & Future Planning (MSIP) and Institute for Information & communications Technology Promotion (IITP) in the digital content source technology development program 2013. [Project Title: Development of Performance Analysis and Generation Technology for Experiencing, Learning and Creating Traditional and Popular Dances, Project No. 10044309].

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