

# Correlation of Pressure Pain Threshold with Segmental Water Content among Female Farmers

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Body composition (BC) is related to the pathogenesis of musculoskeletal disease, especially research focused on the role of fat and muscle mass. This study aimed to identify the associations between the pressure pain threshold (PPT) and pain-related factors including BC. A total of 64 healthy farmers (21 males and 43 females) were recruited, and baseline data were analyzed cross-sectionally. Demographic characteristics (sex, age, marital status, education duration, current status of smoking and alcohol drinking, height, body weight, and underlying diseases) and a psychologic characteristic (a Korean version of the Beck Depression Inventory [BDI]) were assessed. Additionally, body composition analysis using bioelectrical impedance analysis (BIA) was performed. PPT was measured by applying an increasing amount of blunt pressure using a 1 cm<sup>2</sup> hard rubber end at the thenar region of the right hand with a constant increase in pressure of 50 kPa/s. The PPT was measured on a single day, and the average value was used for analysis. The male group (67.00 ± 9.12 years) was older than the female group (62.21 ± 6.77 years;  $p = 0.021$ ). In the body composition analysis, only segmental water of the right arm was positively related to PPT ( $\beta = 0.331$ ,  $p = 0.030$ ) in the multivariate linear regression analysis. In conclusion, hydration status was related to PPT with clinical implication that sufficient hydration could reduce the pain susceptibility. Thus, when assessing the painful condition, checking the hydration status could be helpful before the intensive treatment.

**Keywords:** bioelectrical impedance analysis; body composition; hydration; pressure pain threshold; segmental water analysis

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## Introduction

Musculoskeletal pain is an important clinical and public health problem in recent years because of its effects on work performance and quality of life (Tuzun 2007; de Vries et al. 2013). Musculoskeletal pain initially begins by sensitization at the periphery, but later becomes chronic by sensitization and modification of the central nervous system (Graven-Nielsen and Arendt-Nielsen 2010). This process is known to be influenced by personal factors such as individual characteristics (age, height, weight, sex, smoking, drinking, education, number of children, etc.), occupational factors, medical history, and psycho-organizational factors (stress symptoms, social support, and mental status) (Malchaire et al. 2001).

The recent evidence suggests that body composition (BC) is related to the pathogenesis of musculoskeletal disease, especially research focused on the role of fat and muscle mass (Giles et al. 2008; Yoo et al. 2014). Previous

studies have used weight and body mass index (BMI) as measures of obesity, but these do not allow examination of BC (muscle and fat mass). Several previous studies showed limited results that greater fat mass, but not lean tissue mass, is associated with greater levels of low back pain and disability (Urquhart et al. 2011), incident foot pain (Butterworth et al. 2013), and early structural changes at the knee, which are predictors of knee osteoarthritis (cartilage defects, bone marrow lesions, and decreased cartilage volume) (Wang et al. 2007; Berry et al. 2010), reflecting the overweight burden. Based on these studies, recent BC analysis using bioelectrical impedance analysis (BIA) has been widely used, and enabled us to comprehensively analyze not only the amount of fat and muscle, but also the water composition in each part of the body.

Previously, subjective pain measures such as the visual analog scale and numerical rating scale were used, but in recent years, methods for quantifying pain have been developed. The pressure pain threshold (PPT) measured using

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algometry is a useful parameter in assessing pain sensitivity and the effects of treatment for musculoskeletal pain (Park et al. 2011).

Identifying the relationship between the above-mentioned pain-related demographic, anthropometric and psychosocial factors and musculoskeletal pain, which has not yet been established, is the most important and primary step in the treatment of musculoskeletal pain. Prior review about the meaningful association between pain susceptibility and related factor could improve the clinical treatment outcome. Thus, the aim of this study was to examine the associations between PPT and pain-related factors (individual characteristics, occupational factors, medical history, psycho-organizational factors, and BC) as a comprehensive view of pain susceptibility.

## Materials and Methods

### *Study participants*

Seventy-five healthy farmers (23 males and 52 females) were recruited from November 2017 to December 2018. This study is a cross-sectional analysis of initial baseline data designed as a randomized controlled study about a cognitive training program, which composed with single physical training group (baseline) or dual task (cognitive training superimposed with physical training) training group.

Participant recruitment guidelines were that participants living independently in three rural villages did not have functional limitations or active disease in their lives, and thus they could participate in a training program for 4 weeks. Farmers, who had serious active diseases or neurologic sequelae and could not participate in training program functionally, were excluded at initial step. Finally, participants who had previous history of stroke ( $n = 3$ ) and diabetes mellitus ( $n = 8$ ) were excluded in the analysis step, therefore, data of 64 participants (21 males and 43 females) were analyzed. All females were menopausal status.

Baseline demographic characteristics such as the participant's sex (male/female), age (years), marital status (single/couple), education duration (years), the current status of smoking and alcohol drinking (No/Yes), height (cm), body weight (kg), and underlying diseases and status of medication were assessed. Moreover, to identify the complications of underlying disease, the status of additional related treatment during past 1 year was also assessed.

BMI ( $\text{kg}/\text{m}^2$ ) was calculated as weight in kilograms divided by the square of height in meters. Additionally, as a psychologic characteristic, the Beck Depression Inventory score was assessed (Rhee 1995).

### *Body Composition analysis*

BC analysis using the BIA method was conducted using a body water analyzer (InBody S10®, InBody Corp., Seoul, South Korea). After the subjects stood on the platform and grasped the handgrips of the electrodes with both hands, several BC parameters including BC, muscle-fat body composition (MF), percent body fat (PBF), skeletal muscle mass (SMM), intracellular water (ICW), extracellular water (ECW), total body water (TBW), segmental lean body composition (SL), segmental water body composition (SW), BMI, and basal metabolic rate were automatically calculated. SL and SW were performed about the trunk and four limbs: right arm (RA), left arm (LA), right leg (RL), and left leg (LL).

### *Pressure Pain Threshold*

Regarding pain assessments, PPT was performed applying an increasing amount of blunt pressure using the 1- $\text{cm}^2$  hard-rubber end of an FDA-approved assessment device (Commander Algometer, JTECH Medical, Salt Lake City, UT, USA) (Geletka et al. 2012) on a single day. The pressure was applied to the right thenar region with an approximately constant increase in pressure of 50 kPa/s. The PPT was defined as the amount of pressure with which the subject started to perceive pain. This procedure was repeated 3 times, and the average value was used for analysis.

### *Ethics committee*

This study was approved by the Institutional Review Board (IRB # 2017-04-017-006) and was registered at the Clinical Research Information Service, number KCT0002366. Written informed consent was obtained from all subjects participating.

### *Statistical analysis*

Comparisons between groups were analyzed using the unpaired t-test for continuous variables and chi-square test for categorical data. Partial Pearson's correlation coefficients between each component of the muscle and fat masses and PPT were analyzed by gender to show their associations adjusted by BMI, age, and BDI. To analyze the association between BC and PPT, multivariate linear regression analyses in female farmers were performed with PPT as the dependent variable for significant results. P-values less than 0.05 were considered statistically significant. All data were analyzed using the Statistical Package for the Social Sciences, version 20.0 (SPSS, Chicago, IL, USA).

## Results

### *Demographic characteristics*

Table 1 shows the baseline demographic characteristics of the study participants by sex. The male group was older than the female group ( $p = 0.021$ ), and the alcohol drinking ( $p = 0.025$ ) and education duration ( $p = 0.001$ ) rates were statistically higher in the male group. The values of BMI, smoking, marriage status, the prevalence of hypertension, hypertension medication, cancer history, and BDI were not statistically different between the two groups. PPT measurements were statistically significantly higher in the male group than in the female group ( $p = 0.028$ ).

### *PPT between categorized variables*

PPT values were compared in Table 2 based on the status of categorized variables and clinical cut-off values. Because of the noticeable differences of age, alcohol drinking, and education duration in Table 1, the data of male and female subjects were analyzed separately. In both sexes, there was no significant difference between groups when divided into two groups at 65 years of age. The differences in PPT between groups according to marital status, smoking and drinking status, history of hypertension, hypertension medication, and cancer history were not statistically significant in both genders. All single farmers ( $n = 4$ ) were current alcohol consumer ( $p = 0.043$ ), which may be related to PPT. When the groups were delineated by a score of 16 as

Table 1. Demographic characteristics.

Variables	Male (n = 21)	Female (n = 43)	p value
Age (year)	67.00 ± 9.12	62.21 ± 6.77	0.021
BMI (kg/m <sup>2</sup> )	25.26 ± 2.73	25.82 ± 2.87	0.458
Alcohol drinking*	14 (66.7 %)	16 (37.2 %)	0.025
Smoking*	2 (9.5 %)	0 (0 %)	0.104
Marriage status*	20 (95.2 %)	40 (93.0 %)	1.00
Education duration (years)	10.62 ± 3.81	7.35 ± 3.35	0.001
Hypertension* <sup>#</sup>	9 (42.9 %)	20 (46.5 %)	1.00
Cancer history*	3 (14.3 %)	5 (11.6 %)	1.00
BDI	5.24 ± 4.69	8.00 ± 7.64	0.135
PPT (N/cm <sup>2</sup> )	45.13 ± 7.84	39.68 ± 9.60	0.028

Values are the mean ± standard deviation or number of participants (%).

BMI, body mass index; BDI, Beck Depression Inventory; PPT, pressure pain threshold.

\*Chi-square test for categorical data.

<sup>#</sup>All of the indicated participants had medication for hypertension.

the optimal cut-off point for the BDI when screening for major depression (Jo et al. 2007), the value of PPT was not statistically different with BDI scores in both sexes. There was no difference in PPT between groups when obesity was defined as BMI 25 kg/m<sup>2</sup> or more (Kim et al. 2014) in both sexes.

#### *Partial correlation coefficients between PPT and BC*

PPT and BC analysis using BIA is shown in Table 3. In male group, the correlation between PPT and all BC parameters (BC-Protein, BC-Mineral, BC-Body fat, SMM, MF-Body fat, MF-PBF, SL-RA, SL-LA, SL-Trunk, SL-RL, SL-LL, ICW, ECW, TBW, SW-RA, SW-LA, SW-Trunk, SW-RL, and SW-LL) was not statistically significant in both the unadjusted and adjusted analyzes for age, BMI, and BDI. In female group, PPT and BC in the unadjusted measurements showed positive correlations in SW-RA ( $p < 0.05$ ). In partial correlation coefficient analysis, PPT and BC adjusted for age, BMI, and BDI showed positive correlations with  $p < 0.05$  in the SW-RA in female group.

#### *Multivariate linear regression between PPT and BC*

Table 4 shows the results of multiple linear regression for parameters ( $p < 0.40$ ) after performing the partial correlation between PPT and BC adjusted for age, BMI, and BDI. Multivariate linear regression analysis was performed only in female group because there was no significant difference in partial correlation coefficients in male group. BC-Body fat, MF-Body fat, and SW-LA were not statisti-

cally significant and only SW-RA was statistically significant ( $p = 0.030$ ) with positive correlation.

## **Discussion**

This study was designed to identify the factors related to PPT as an initial step of treating musculoskeletal pain based on the hypothesis that a coping strategy for the proven related factor might reduce the pain and be an adjuvant approach in addition to the established treatment plan. This study showed that segmental water on the right arm was significantly related to the PPT measured at the right thenar region with the assumption that pain susceptibility was reduced by hydration.

Several previous studies revealed that BIA was a reliable and valid technology for correlating musculoskeletal pain with BC (Iizuka et al. 2015; Walsh et al. 2018). The studies mainly focused on body fat or body muscle, and elevated body fat may confer increased risk of incident and worsening pain by a pro-inflammatory adipokine (leptin) or inflammatory mediators (e.g., tumor necrosis factor- $\alpha$ , interleukin-6) (Sommer and Kress 2004; Younger et al. 2016). In another study (Iizuka et al. 2015), total body water was reported as a factor associated with upper extremity pain, but only total body water ratio, not that associated with pain sites, was studied. However, their study did not show that the PPT measured in the right thenar muscle was related to the segmental water in the right arm.

Little is known about the relationship between the

Table 2. Comparison of PPT between categorized variables.

Variables	Male (n = 21)		Female (n = 43)		
	PPT	p value	PPT	p value	
Age	< 65 years	47.84 ± 4.73 (n = 9)	40.09 ± 9.81 (n = 13)	0.143	0.400
	≥ 65 years	43.10 ± 9.21 (n = 12)	38.61 ± 8.57 (n = 30)		
Marriage	Single	50.00 ± 0.00 (n = 1)	43.17 ± 6.30 (n = 3)	0.538	0.521
	Couple	44.89 ± 7.96 (n = 20)	39.42 ± 9.81 (n = 40)		
Alcohol	No	47.86 ± 3.13	39.79 ± 9.61	0.271	0.930
	Yes	43.77 ± 9.17	39.51 ± 9.91		
Smoking	No	44.62 ± 8.08	39.68 ± 9.60	0.369	N/A
	Yes	50.00 ± 0.00	-		
Hypertension <sup>#</sup>	No	44.88 ± 7.10	38.18 ± 10.43	0.867	0.275
	Yes	45.48 ± 9.17	41.42 ± 8.47		
Cancer history	No	45.70 ± 7.86	39.00 ± 9.74	0.431	0.200
	Yes	41.73 ± 8.30	44.90 ± 7.16		
BDI	< 16	45.13 ± 7.84 (n = 21)	40.44 ± 9.81 (n = 35)	N/A	0.334
	≥ 16	- (n = 0)	36.71 ± 9.29 (n = 8)		
BMI	< 25 kg/m <sup>2</sup>	43.48 ± 8.23 (n = 9)	37.59 ± 10.01 (n = 13)	0.416	0.353
	≥ 25 kg/m <sup>2</sup>	46.38 ± 7.65 (n = 12)	40.59 ± 9.45 (n = 30)		

Values are the mean ± standard deviation.

PPT, pressure pain threshold; BDI, Beck Depression Inventory; BMI, body mass index.

<sup>#</sup>All of the indicated participants had medication for hypertension.

water composition and pain at the same site because only systemic studies have been performed. Some of the mechanisms and variables involved in pain perception are influenced by hypohydration (Bear et al. 2016). Dehydration reduces the pain threshold and alters activation of the pain centers of the brain as seen by functional magnetic reso-

nance imaging, while rehydration with an oral rehydration solution decreases brain activity related to painful stimuli (Ogino et al. 2014). However, the mechanism of the increase in pain perception due to hypohydration is still unclear.

Hypohydration increases the sensitivity of pain by

Table 3. Partial correlation coefficients between PPT and body composition adjusted by age, BMI, and BDI.

Variables	Male (n = 21)		Female (n = 43)	
	Unadjusted	Adjusted	Unadjusted	Adjusted
BC-Protein	0.130	-0.175	0.060	-0.037
BC-Mineral	0.082	-0.187	0.091	0.041
BC-Body fat	0.170	0.156	0.018	-0.163
SMM	0.132	-0.193	0.101	0.010
MF-Body fat	0.170	0.156	0.017	-0.165
MF-PBF	0.127	0.176	-0.032	-0.142
SL-RA	0.236	-0.025	-0.017	-0.119
SL-LA	0.149	-0.177	-0.011	-0.115
SL-Trunk	0.122	-0.216	0.140	0.060
SL-RL	0.086	-0.208	0.090	0.009
SL-LL	0.136	-0.133	0.061	-0.047
ICW	0.115	-0.216	0.087	-0.001
ECW	0.105	-0.158	0.172	0.110
TBW	0.108	-0.200	0.116	0.037
SW-RA	0.020	-0.300	0.331*	0.349*
SW-LA	0.057	-0.273	0.270	0.276
SW-Trunk	0.119	-0.207	0.184	0.129
SW-RL	0.103	-0.167	0.063	-0.029
SW-LL	0.093	-0.215	0.063	-0.032

BDI, Beck Depression Inventory; BMI, body mass index; PPT, pressure pain threshold; BC, body composition; MF, muscle-fat body composition; PBF, percent body fat; SMM, skeletal muscle mass; SL, segmental lean body composition; RA, right arm; LA, left arm; RL, right leg; LL, left leg; ICW, intracellular water; ECW, extracellular water; TBW, total body water; SW, segmental water body composition.

\*p value < 0.05.

increasing the concentration of cortisol in the blood (van Rosendal et al. 2015). Pain perception is directly associated with cortisol and indirectly associated via cortisol through the regulation of the immune system (al'Absi et al. 2002). Evidence for this is that patients with an increased cortisol concentration have a high pain rating score and low pain

thresholds when given electrical stimulation (Choi et al. 2012). In addition, pain recurrence can be affected by the concentration of cortisol (Quartana et al. 2010). Meanwhile, Ogino et al. (2014) suggested that hypohydration acts on the pain sensory cortex, thereby activating the pain transmission pathway.

Table 4. Multiple linear regression between PPT and body composition in female group.

Variables	Female (n = 43)	
	Beta	p value
BC-Body fat	-0.140	0.393
MF-Body fat	-0.142	0.387
SW-RA	0.331	0.030
SW-LA	-0.131	0.697

BC, body composition; MF, muscle-fat body composition; SW, segmental water body composition; RA, right arm; LA, left arm; PPT, pressure pain threshold.

The present study found that among the individual characteristics, PPT values differed according to sex. All females were menopausal in the present study. Numerous studies have reported lower PPTs in females than in males and are associated with the menstrual cycle (Chesterton et al. 2003; Kowalczyk et al. 2010). These studies reported that premenopausal women have lower thresholds of pain than men, but sex-related pain thresholds are not different between males and postmenopausal females. Differences in pain thresholds due to differences in social roles, such as the type of work between males and females, were also reported (Fillingim et al. 2009). Testosterone production may be indirectly associated with cortisol's involvement in key pain regulation processes (Choi et al. 2012). Testosterone reduces pain through inhibitory effects in the thalamus and the middle frontal cortex; therefore, cortisol causes sensitization to pain by decreasing testosterone (Choi et al. 2011). This suggests that females with lower levels of testosterone respond more sensitively to pain than males do.

Psycho-organizational factors should be considered as related factors to the PPT. On an average, 65% of patients with depression complain of persistent pain (Bair et al. 2003), and patients with both depression and chronic pain have worse prognosis and outcomes than those with each illness alone (Arnow et al. 2006). The exact mechanism between pain and depression is not known, but many factors are known to be at work. A recent meta-analysis revealed that the contrasting patterns for ischemic versus other noxious stimuli suggest that stimulus modality is a key factor (Thompson et al. 2016).

In comparing the PPT between males and females, PPT values were lower in females than in males, and there were differences in age, alcohol drinking, and education duration between the two groups. Although older age increases sensitivity to mechanically evoked pain (El Tumi et al. 2017), some studies have reported that older age decreases sensitivity to pain (Yeziarski 2012). In a meta-analysis study, each study reviewed had different criteria for delimiting young and old groups, and the mean age of each group was different (El Tumi et al. 2017). In our study, the

age of the female group was younger and had a lower pain threshold than the male group. However, there was no difference in pain threshold between younger and older groups when the age of 65 years was used as the criterion for defining the elderly. Further studies on the changes in pain threshold according to age and sex are needed. Nicotine (from cigarette smoke) and alcohol drinking have analgesic effects in humans and experimental animals (Ditre et al. 2016; Thompson et al. 2017). Nevertheless, studies with contradictory results have been published, and our study showed no difference in the threshold of pain according to the presence or absence of alcohol drinking and smoking. It is necessary to analyze not only the present state but also past personal history.

There are several limitations to this study. First, this was a single-center study, thus, the study population is relatively small, which has significant inherent limitations to the generalizability of its findings. Generalization through large-scale research is necessary. Second, it is necessary to investigate the correlation of the PPT with the segmental water of each limb by measuring PPT in both upper and lower extremities to rule out the specificity of the dominant hand. Third, a baseline laboratory study for scientific proof of the effects of hydration on pain threshold should be performed in the future. Fourth, it is necessary to analyze the effect of the underlying disease (e.g., musculoskeletal disorders, diseases that can cause radiating pain, joint diseases) at the site of PPT. Fifth, although this study involved multiple patients with cross-sectional analysis, it did not consistently follow a single patient. If we change the hydration in one patient, we can get a clearer result if we look at the change of segmental water and the correlation of PPT at that time. Thus, for the more concrete results, large study population could be needed in the further study.

In summary, we herein investigated the association between PPT and related factors. BC analysis using BIA showed that the segmental water was related to the PPT in female group. Segmental water analysis in painful areas will help to study the relationship between pain and water composition. When patients are presenting with musculoskeletal pain complaints, it might be possible to reduce the medical costs by raising the threshold of pain simply by supplementing the lack of hydration through segmental water analysis instead of using medicine, physical therapy, and local injection. In addition, sufficient hydration in daily life can improve the quality of life by reducing the frequency and intensity of pain as results of pain threshold increase.

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## Conflict of Interest

The authors declare no conflict of interest.

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