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DIFFERENCE IN PERCEIVED PAIN INTENSITY DEPENDING ON THE ORDER OF SUBMAXIMAL ISOMETRIC CONTRACTIONS PERFORMED AT DIFFERENT INTENSITIES

ORIGINAL ARTICLE

ABSTRACT

Purpose: Previous studies that examined pain after submaximal isometric contractions at different intensities are limited in that they used different intensities randomly. The present study aimed to examine the change in pain depending on the order of submaximal isometric contractions performed at two different intensities and inter-and intra-individual differences in pain responses.

Methods: Twenty-nine volunteers participated (mean age=22.10±1.60 years) to the study. Hamstring flexibility was measured in the supine position. Maximal voluntary contraction (MVC) was measured during hip extension. Submaximal contractions were performed at two different target intensities: 25% and 75% of MVC. Visual Analogue Scale (VAS) was used to measure the pain after submaximal contractions. Group A (n=15) performed submaximal contraction in 25% to 75% of MVC in the 1st period and 75% to 25% of MVC in the 2nd period. In Group B (n=14), the submaximal contraction was performed in each period in the opposite order of Group A.

Results: There was a significant decrease in pain in Group B during the 2nd period (p<0.05). The VAS at 75% of the MVC showed a significant decrease at 25% of the MVC (p=0.011). Correlations were observed between flexibility and 1st-period VAS score (p=0.048) and 2nd-period VAS score (p=0.036) and between the VAS scores in the 1st and 2nd periods (p<0.001).

Conclusion: Pain intensity could be perceived differently depending on the order of sequential application, even when the intensities are identical, and might be more clinically useful in the analysis of intra-individual comparisons.

Key Words: Hamstring Muscles; Isometric Contraction; Pain; Range of Motion.

FARKLI YOĞUNLUKLARDA YAPILAN SUBMAKSİMAL İZOMETRİK KONTRAKSİYONLARIN SIRASINA BAĞLI OLARAK AĞRI ALGISINDA OLUŞAN FARKLILIK

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Farklı yoğunluklarda submaksimal izometrik kontraksiyondan sonra ağrıyı inceleyen önceki çalışmalar, farklı yoğunlukları rastgele sırayla kullanmaları nedeni ile yetersizdir. Bu araştırmanın amacı, iki farklı yoğunlukta yapılan submaksimal izometrik kontraksiyonların sırasına bağlı olarak ağrı algısında meydana gelen değişikliği ve ağrı cevabındaki bireyler arası ve birey içi farklılıkları incelemekti.

Yöntem: Çalışmaya 29 gönüllü birey katıldı (yaş ortalaması=22,10±1,60 yıl). Hamstring esnekliği sırtüstü pozisyonda ölçüldü. Kalça ekstansiyonu sırasında maksimal istemli kontraksiyon (MİK) ölçüldü. Submaksimal kontraksiyonlar, MİK'in % 25'i ve % 75'i olmak üzere iki farklı hedef yoğunlukta gerçekleştirildi. Submaksimal kontraksiyonlardan sonra ağrıyı ölçmek için Visual Analog Skalası (VAS) kullanıldı. Grup A (n=15) 1. periyotta MİK'in % 25'inden % 75'ine ve 2. periyotta MİK'in % 75'inden % 25'ine olacak şeklinde submaksimal konraksiyon gerçekleştirdi. Grup B'de (n=14) ise, maksimal kontraksiyon her periyotta A grubunun tersi sırada gerçekleştirildi.

Sonuçlar: Grup B'de 2. periyot boyunca ağrıda anlamlı bir azalma vardı (p<0,05). MİK'in % 75'i düzeyinde ölçülen VAS, MİK'in % 25'i düzeyinde ölçülen VAS değerine göre önemli düzeyde azalma gösterdi (p=0,011). Birinci (p=0,048) ve 2. periyotta (p=0,036) esneklik ile VAS skoru arasında ve 1. ve 2. periyotta VAS skorları arasında (p<0,001) ilişki bulundu.

Tartışma: Ağrı şiddeti, uygulama sırasına bağlı olarak, yoğunluklar aynı olsa bile farklı şekilde algılanabilir ve bireysel karşılaştırmaların analizinde klinik olarak daha yararlı olabilir.

Anahtar Kelimeler: Hamstring Kasları; İzometrik Kontraksiyon; Ağrı; Hareket Açıklığı.

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INTRODUCTION

There are three main types of pain: nociceptive, neuropathic, and inflammatory and each type are responded to by different stimuli (1). The most common type is nociceptive pain and is caused by tissue injury. In the sports field, strenuous exercise requires repeated muscle contractions at high-intensity; this could lead to the damage of contractile and non-contractile tissues (2). The injury of soft muscle tissue induces primary pain, and inflammation in the region of the injury induces secondary to pain (3). Previous studies examining pain in muscle tissues have confirmed that the quality and quantity of pain could be differently responded depending on types of muscle contractions or exercise intensity (4-6).

In the literature, there are many comparative studies on concentric or eccentric exercises that shorten or lengthen the muscle length, and tissue damage and pain are more significant in eccentric exercises (4). In contrast, the research on isometric exercises that does not change the muscle length is relatively sparse. Isometric contraction is widely used clinically to increase the muscle flexibility in shortened muscles and to maintain muscle performance in the acute and/or subacute stage; therefore, research in this field is necessary (7). Secondly, in research related to exercise intensity, pain is found to be relatively high at high-intensity, and there is a potential risk of muscle tissue damage. However, prior studies are limited in that they used different intensities in a randomized order (8,9). Because pain is affected complexly by diverse factors, it is necessary to examine its intensity gradually increasing or decreasing rather than in a randomized condition only (10). It is well known that exercise stimulates the release of endogenous opioids, and it could elicit different reactions depending on the intensity (11,12). Strength of the earlier exercise may affect the perception of the pain that occurs after the later exercise, such that the final quantitative value of pain may differ. According to the previous preliminary study, when three different intensities were applied in a gradual increase or decrease, the perceived exertion appeared differently in the given intensity. It signifies that individual physical sensation during exercise could be affected by order of intensity. As the perceived exertion is related to pain, it could be reasonably hypothesized that pain could also be differently perceived depending on the order of intensity (13). In addition, the pain might be affected by individual physiological factors such as inherent flexibility, and the biological response may differ according to the exercise intensity (14-16). Even without severe illness, inter-individual differences in pain intensity were observed (17). The purpose of this study was to examine the change in pain intensity depending on the order of submaximal isometric contractions and the inter-and intra-individual differences in pain responses. Two different intensities were applied in a gradual increase or decrease to two groups.

METHODS

Subjects

Twenty-nine sedentary healthy adults (13 males, 16 females) participated in this experimental study. Volunteer sample was obtained by advertising on posters. The inclusion criterion was an active knee extension (AKE) greater than 20° (18). Subjects were excluded if they had pain in their hip or knee joints. Informed consent was obtained from all subjects before participation in this study. The Institutional Review Board of Woosong University approved the study (Approval Date: 10.11.2019 and Approval Number: 1041549-191011-SB-81). This study was conducted at university-based rehabilitation science institute for two months from March 2020.

Procedures

Hamstring flexibility was measured in random order via AKE and passive straight leg raise (PSLR) (19). For the AKE test, each subject lay in the supine position on a treatment table and performed 90° flexion of the hip and knee joint (20). Each subject then engaged in knee extension slowly until hamstrings tightness was felt (Figure 1A). At the maximal knee extension, the angle between the vertical line and knee extension was measured using a universal goniometer (Fabrication Enterprises Goniometer, New York, USA). The PSLR was also measured in the supine position, as was the AKE. The examiner maintained the full extension of the knee joint and slowly raised the lower extremity. Leg raising was performed until discomfort or pain due to muscle tightness was felt. The hip extension angle was measured by a goniometer. Immediately after measuring the PLSR angle, pain intensity was measured using the Visual Analogue Scale (PSLR-VAS). The perceived pain level was assessed using the VAS consisting of a 10-cm line that represents the continuum of “no pain” to “worst pain” (21). After measuring the hamstring flexibility, three trials (6 s/trial, 5-s rest between trials) of maximal voluntary contraction (MVC) were measured during hip extension (22). Pain intensity (MVC-VAS) was measured immediately after the MVC performance.

During MVC, one end of the sling wire was connected to the ankle strap, and the other end was connected to the sling system (Marpe Inc., Jeonju, South Korea) fixed on the ceiling to help with the isometric contraction of the lower extremity (Figure 1B) (23). Verbal encouragement was provided to the subjects during MVC. After the resting period, three trials (6 s/trial, 5-s rest between trials) of submaximal contractions at two different target intensities (75% and 25% of MVC) were performed for both extremities. After three trials of submaximal contractions at the assigned target intensity, the VAS was used to measure the pain (Sub-VAS), and 3-min rest was provided between different intensities. Subjects were randomly divided into two groups. In both groups, the values for the left and right lower extremities were measured during the 1st and 2nd period, respectively. Group A performed submaximal contraction in 25% to 75% of MVC in the 1st period and 75% to 25% of MVC in the 2nd period. In Group B, the submaximal contraction was performed in each period in the opposite order of group A.

Statistical Analysis

The normality of the data was tested using the Shapiro-Wilk test. Age, height, weight, body mass index (BMI), PSLR, AKE, and VAS between group A and B were subjected to the Mann-Whitney U test. The VAS scores measured at two different target intensities during the 1st and 2nd period were tested with the Friedman test and with Wilcoxon pairwise post hoc tests. The relationship between flexibility, measured by PSLR or AKE, and the VAS and the relationship between flexibility of the left and at right lower extremities were tested using Spearman’s rank correlation (24). Data analysis was performed using IBM SPSS Statistics 25 (IBM Corp., Armonk, NY, USA). The statistical significance was set at p<0.05. The values were reported as mean±standard deviation. G*Power version 3.1.9.7 (Universität Kiel, Kiel, Germany) was used for sample size estimation using an effect size of 0.50, significance level of 0.05, and 80% power of the study.

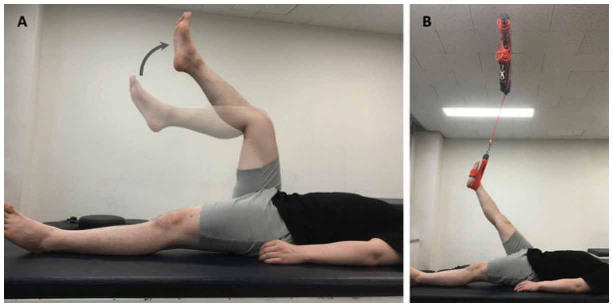

Figure 1: (a) Active Knee Extension Test and (b) Isometric Contraction of the Lower Extremity.

RESULTS

There was no significant difference in the characteristics of the subjects, such as age, height, weight, and BMI between the two groups (Table 1). Additionally, there was also no significant difference in PSLR in the 1st period (p=0.400) and the 2nd period (p=0.561), AKEs in the 1st period (p=0.477) and the 2nd period (p=0.983) (Table 2).

There was 0.36 and 0.40 decrease from 75%-25% in the 1st and 2nd periods, respectively, without

Table 1: Characteristics of the Subjects.

Variables	Total Participants (n=29)	Group A (n=15)	Group B (n=14)	p
	Mean±SD	Mean±SD	Mean±SD	
Age (years)	22.10±1.60	22.30±1.60	21.90±1.30	0.847
Weight (kg)	61.90±12.00	63.50±13.40	60.30±11.10	0.400
Height (cm)	165.80±8.20	166.30±8.60	165.40±8.30	0.914
Body Mass Index (kg/m^2)	22.40±3.00	22.80±3.50	21.90±2.50	0.425

Table 2: Hamstring Flexibility at Baseline.

Variables	Passive Straight Leg Raise (°)			Active Knee Extension (°)		
	Group A (n=15)	Group B (n=14)	p	Group A (n=15)	Group B (n=14)	p
	Mean±SD	Mean±SD		Mean±SD	Mean±SD	
1st Period	66.30±11.30	62.60±14.40	0.400	26.90±14.00	30.00±14.70	0.477
2nd Period	63.60±11.90	61.40±11.30	0.561	32.10±14.50	31.20±11.20	0.983

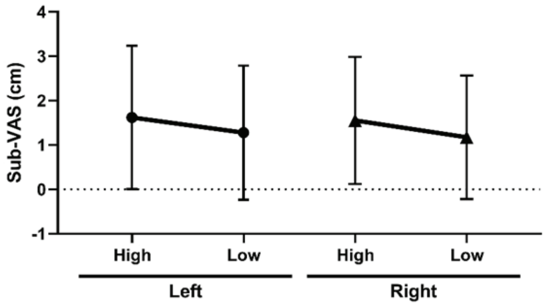

Figure 2: Changes in Visual Analogue Scale without Differentiating between the Groups.

considering intensity order (mean VAS was calculated at each intensity without differentiating the groups). Sub-VAS was not significantly different, although it slightly and continually decreased with the reduction in intensity (Figure 2).

In within-group comparisons, there was a significant difference in the Sub-VAS, depending on intensities in both groups. In Group A, a 0.63 decrease from 75% to 25% was found in the 2nd period. At the same time, there was a 0.86 decrease from 75% to 25% in Group B in the 1st period. The Sub-VAS at 75% of the MVC showed a significant decrease at 25% of the MVC (p=0.011) (Figure 3).

There was a weak significant correlation (r=-0.371, p=0.048 during the 1st period and r=-0.391, p=0.036 during the 2nd period) between PSLR and MVC-VAS. However, there was no significant relationship (r=-0.084, p=0.666 during the 1st period and r=-0.080, p=0.680 during the 2nd period) between AKE and MVC-VAS. In PSLR-VAS (r=0.954, p<0.001) and MVC-VAS (r=0.888, p<0.001), there was a strong correlation between the values for the 1st and 2nd period (Table 3).

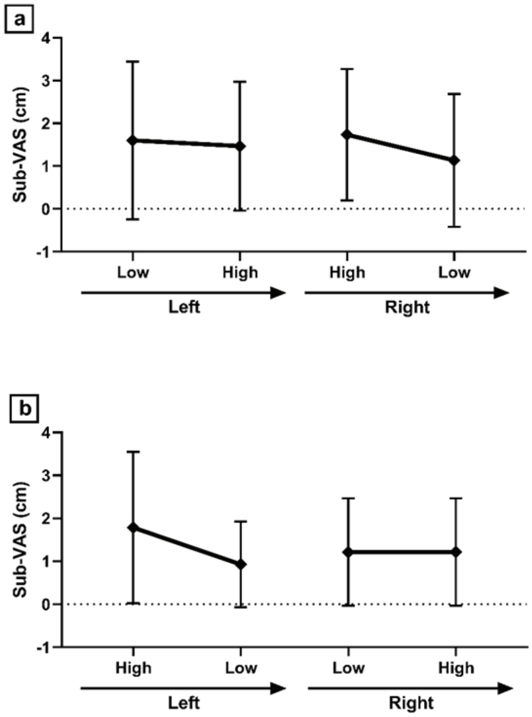

Figure 3: Changes in Visual Analogue Scale in (3a) Group A and (3b) Group B.

DISCUSSION

The levels of pain intensity levels while controlling for the effect of the order of intensity (by using

Table 3: Pain Intensity at Passive Straight Leg Raise and Maximal Voluntary Contraction.

Variables	PSLR-VAS		MVC-VAS	
	Group A (n=15)	Group B (n=14)	Group A (n=15)	Group B (n=14)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
1st period	2.70±2.00	2.40±2.1.65	2.40±1.70	2.14±1.70
2nd period	2.50±1.50	2.77±2.22	2.20±1.50	2.29±1.98
p	**<0.001***	**<0.001***	**<0.001***	**<0.001***

*p<0.05. MVC: Maximal Voluntary Contraction, PSLR: Passive Straight Leg Raise, VAS: Visual Analogue Scale.

mean VAS from all subjects without differentiating between the groups) showed that pain decreased slightly when the intensity was reduced from 75% to 25% of MVC during both the 1st and 2nd period, however it was not statistically different. These were similar to previous findings reporting no decrease in pain between 75% and 50% and between 70% and 40% of the MVC (8,9). However, different submaximal isometric contractions were provided in a randomized order. In this study, we performed analyses on the two groups separately to identify the effect of the order of intensity. A pattern different from that obtained with the same analysis on all subjects was observed. Furthermore, this pattern was identical for both groups. In both Group A and B, there was no change in pain despite a gradual increase in intensity. In contrast, the pain had significantly decreased in the period of the gradual decrease in intensity. Compared to the analyses of all subjects, the decrease had about doubled. These two results signify that caution must be taken when interpreting the results of the previous experiments that were conducted in randomized order. The decrease in the pain level between intensities may be offset in a randomized order, resulting in a phenomenon of the difference appearing to be smaller than it is. The quantitative pain level perceived when experiencing low-intensity contraction for the first time, and the quantitative pain level perceived in subsequent low-intensity contractions after experiencing a significant amount of pain from high-intensity contraction beforehand may differ. Perhaps, the significantly high level of pain that occurs after the muscle contraction at high intensity is a reference for the quantification of subsequent pain. For women who have experienced extreme pain through actual childbirth, the subjective definition of the highest level of pain may change after childbirth, which may change the degree of pain perception under the same conditions (25). The range of pain level matching severe, moderate, and mild pain is reported differently depending on the illness (26,27). Secondly, increased pain tolerance by exercise-induced hypoalgesia at high-intensity could have affected the perception of pain at subsequent contractions at low-intensity (12,28). High-intensity exercise is known to stimulate the endogenous opioid system. Among athletes, high pain tolerance is observed after exposure to high-intensity exercise (29). In this study, the finding of a relatively large reduction in pain in response to a gradual decrease in intensity supports this hypothesis. It could be concluded that sequentially applying diverse intensities rather than applying a single intensity could result in different changes in pain, depending on the order of the intensity.

Interestingly, there was a significant relationship between hamstring flexibility measured by the PSLR test and pain measured after MVC. However, there was no significant relationship between hamstring flexibility measured by the AKE test and pain measured after MVC. This difference requires an understanding of the muscles involved during the PSLR and AKE test. The flexibility measured during PSLR includes the tightness of not only the hamstrings but also of other hip extensors (30). In contrast, because the hip and knee joint are maintained at 90° during AKE, pelvis fixation is possible. In this manner, hamstring activation could be selectively induced. In the study by Worrell et al., higher hamstring electromyography (EMG) activity was observed during knee flexion than during hip extension (31). Additionally, when the hip flexion angle increased from 0 to 90 degrees, the muscle activity of the gluteus maximus gradually decreased while that of the hamstrings increased (31). Overall, while hamstrings function at both hip and knee joint as biarticular muscles, muscle activation is high during knee flexion. Knee flexion might be preferred over hip extension in order to activate the hamstrings selectively. In this study, the subjects performed hip extension with full extension of the knee during voluntary isometric contractions, and the hamstrings worked as hip extensors.

Flexibility measured by PSLR showed a correlation with the pain that occurred after MVC, but there was no significant correlation with the flexibility measured by AKE. It means the two roles of the hamstrings are not equal. Additionally, a robust correlation of pain between right and left extremities was observed in this study. It is widely known that even if the same number of external stimuli that cause pain are given, there may be differences among individuals in perceiving and expressing it. Pain responses have considerable inter-individual variability, and pain perception is determined by the interaction of factors such as demographic and psychosocial variables (10,32,33). The results of this study show that, unlike the "inter-individual" differences, "intra-individual" pain perception indicates that both the left and right extremities perceive similar levels of pain for the same number of external stimuli. In intra-individual research, the subjective ratings of pain were closely related to the magnitude of brain activation in the somatosensory cortex, anterior cingulate cortex, prefrontal cortex, and insular cortex (34,35). It signifies that individual genetic factors significantly affect pain. Therefore, while the absolute quantity of the external element that causes pain is also essential, the individual characteristics are critical (33). In clinical trials, it would be more meaningful to use intra-individual pain measurements, such as comparing pain levels before and after treatment, than the measurements of pain for comparisons between individuals.

This study did not measure muscle EMG activity. Previous studies have shown that the EMG activity of the agonist's muscle decreased due to the decrease in the motoneuron discharge rate in the case of muscle pain during dynamic contractions, while the EMG activity of the antagonist's muscle increased (35-37). A significant increase in the EMG activity of the agonist's muscle is thought to be a protective mechanism that limits the movement of a painful muscle (37). Additional study on the changes in the EMG activity by order of intensity is needed for an increased understanding of pain. Because this study was conducted on healthy adults, it is difficult to apply the findings to children or the elderly. Further research on diverse populations is required.

Pain is often experienced in the targeted muscle and the surrounding area after high-intensity exercise. It was interpreted as a warning signal and as a part of the protective mechanism (37). However, in this study, it was found that the level of pain could be perceived differently depending on the order of sequential application even when the intensities are identical during a program that combines different intensities. Pain that occurred at high-intensity could decrease in stages along with the decrease in the intensity, but pain may not significantly increase when the intensity is gradually increased from low-intensity. In clinical settings, caution must be taken when adopting the general hypothesis that there would be a positive correlation between the intensity of exercise and quantitative level of pain because the pain level perceived by an individual may be reported to be lower or higher than expected. Furthermore, pain that occurs after submaximal isometric contraction will be more clinically meaningful in the analysis for intra-individual comparison than in the analysis for inter-individual comparison.

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Conflict of Interest: The author declares no conflict of interest.

Ethical Approval: The institutional review board of Woosong University approved this study (Approval Date: 10.11.2019 and Approval Number: 1041549-191011-SB-81).

Informed Consent: A written informed consent form was obtained from all participants.

Peer-Review: Externally peer-reviewed.

Author Contributions: Concept, Design, Supervision, Resources and Financial Support, Materials, Data Collection and/or Processing, Analysis and/or Interpretation, Literature Research, Writing Manuscript, Critical Review – W.L.

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