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Wing Y. Lau
Edith Cowan University

Makii Mishan Muthalib
Edith Cowan University

Kazunori Nosaka
Edith Cowan University

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Visual Analog Scale and Pressure Pain Threshold for Delayed Onset Muscle Soreness Assessment

Wing Yin Lau, MS[1)], Makii Muthalib, PhD[1,2)], Kazunori Nosaka, PhD[1)]

1) School of Exercise and Health Sciences

Edith Cowan University, Joondalup, Australia

2) Institute of Health and Biomedical Innovation,

Queensland University of Technology, Brisbane, Australia

Please address correspondence to:

Wing Yin Lau

School of Exercise and Health Sciences

Edith Cowan University

270 Joondalup Drive, Joondalup, WA 6027, AUSTRALIA

Telephone: 61-8-6304-5073, Fax: 61-8-6304-5036

Email: wlau0@our.ecu.edu.au

ABSTRACT

Objectives: To investigate the relationship between two assessments to quantify delayed onset muscle soreness [DOMS]: visual analog scale [VAS], and pressure pain threshold [PPT].

Methods: Thirty one healthy young men [25.8 ± 5.5 years] performed 10 sets of six maximal eccentric contractions of the elbow flexors with their non-dominant arm. Before and one to four days after the exercise, muscle pain perceived upon palpation of the biceps brachii at three sites [5, 9, and 13 cm above the elbow crease] was assessed by VAS with a 100 mm line [0 = no pain, 100 = extremely painful], and PPT of the same sites was determined by an algometer. Changes in VAS and PPT over time were compared amongst three sites by a two-way repeated measures analysis of variance, and the relationship between VAS and PPT was analyzed using a Pearson product-moment correlation.

Results: VAS increased one to four days after exercise and peaked two days post-exercise, while the PPT decreased largest at one day post-exercise and remained below the baseline for four days following exercise [$P<0.05$]. No significant difference among the three sites was found for VAS [$P=0.62$] or PPT [$P=0.45$]. The magnitude of change in VAS did not significantly correlate with that of PPT [$r=-0.20$, $P=0.28$].

Conclusion: These results suggest that the level of muscle pain is not region specific, at least among the three sites investigated in the study, and VAS and PPT provide different information about DOMS, indicating that VAS and PPT represent different aspects of pain.

KEY WORDS: Palpation, muscle damage, eccentric exercise, algometer, elbow flexors

INTRODUCTION

We often experience muscle pain in the next days following exercise or daily activities, and this type of pain is referred to as delayed onset muscle soreness [DOMS] (1). DOMS is characterized by the sensation of a dull, aching pain, usually felt during movement or palpation of the affected muscles, develops within 24 hours after performing exercise, and peaks 1-3 days post-exercise (1,2). The underlying mechanisms of DOMS have not been fully understood, but it has been documented that damage to contractile proteins, intermediate filaments, and/or connective tissue surrounding muscle fibers, and subsequent inflammatory process are associated with it (1,3). DOMS is considered a mechanical hyperalgesia, which is characterized by an increased sensitivity of nociceptors [type III and IV afferents] to a stimulus (2) and/or allodynia in which pain is induced by a stimulus that does not normally provoke pain (4,5).

To quantify the level of muscle soreness is a challenge due to the subjective nature of pain (6). Different pain scales such as a visual analog scale [VAS] (7), verbal rating scale (8), numerical rating scale (9), and descriptor differential scale (10) have been used in previous studies to assess DOMS. Among them the VAS is most often used for DOMS assessment (7,11), consisting of a certain length of line [e.g., 100 mm] in which one end of the line indicates no pain and the other end indicates worst pain. Since DOMS is not felt when the affected muscle is still, it is necessary to provide a mechanical stimulus to induce the pain such as palpation, contraction, or stretching of the muscle (6,12). The use of VAS to assess musculoskeletal pain has been reported to be reliable (13,14); however, the assessment of palpation soreness by VAS is often criticized because of the ambiguity in the palpation procedure (15).

An alternative way to quantify muscle pain is the use of a pressure algometer that assesses the point where a sensation of pressure changes into a sensation of pain in the muscle,

which is referred to as the pressure pain threshold [PPT] (16,17). The PPT has been demonstrated to be reliable for measuring pain threshold (18,19). Previous studies used PPT to assess DOMS (20,21) and some of the studies applied both VAS and PPT to evaluate DOMS (11,22,23). Our previous studies showed that muscle soreness assessed by VAS peaked at two days, and PPT decreased largest at one day post-exercise and no further decrease was seen at two days following eccentric exercise of the elbow flexors (23,24).

It appears that DOMS assessed by a VAS upon palpation and that by PPT are related, since both measures assess the pain induced by pressure. However, no correlation analysis between VAS and PPT has been performed in previous studies. It is necessary to clarify how the VAS and PPT measures are associated with each other and whether they provide different information about DOMS. Therefore, the purpose of this study was to examine the relationship between VAS upon palpation and PPT of the elbow flexors following eccentric exercise of the elbow flexors.

MATERIALS AND METHODS

Subjects

This study was approved by the Institutional Human Research Ethics Committee and complied with the Declaration of Helsinki. Thirty-one healthy men with no current or previous upper arm injuries and who had not performed resistance training of the upper limbs for at least six months prior to the present study were recruited. Their mean ± standard deviation [SD] age, body weight, and height were 25.8 ± 5.5 years, 70.2 ± 9.5 kg, and 173.4 ± 7.2 cm, respectively. All subjects completed an informed written consent form and a medical questionnaire before participating in the study. Subjects were requested not to change their lifestyle and diet, not take

any anti-inflammatory drugs or nutritional supplements and not perform unaccustomed exercise during the experimental period.

Eccentric Exercise

The exercise consisted of 10 sets of six maximal voluntary eccentric contractions of the elbow flexors on an isokinetic dynamometer [Cybex 6000, Ronkonkoma, NY. USA]. For each eccentric contraction, the elbow joint was forcibly extended from a flexed [90°] to a fully extended position [~0°] in one second [s] at an angular velocity of $90°\cdot s^{-1}$ in a supinated wrist position. The subjects were verbally encouraged to generate maximal force at the flexed position and to maximally resist against the elbow extending action throughout the range of motion. After each eccentric contraction, the isokinetic dynamometer returned the arm to the flexed position at a velocity of $9°\cdot s^{-1}$, which provided a 10-s rest between contractions. The rest period between sets was three minutes. Torque and displacement signals were obtained directly from the dynamometer output and captured using a data acquisition system [PowerLab with a Chart 7 software, ADinstruments, Bella Vista, Australia].

Maximal Voluntary Isometric Contraction Torque

As a marker of muscle damage, maximal voluntary isometric contraction [MVC] torque of the elbow flexors was measured before, immediately after, and one, two, three and four days following exercise. Using the same isokinetic dynamometer [Cybex 6000] and the same positioning of the subjects as described for the eccentric exercise, subjects performed two 3-s maximal voluntary isometric contractions at an elbow joint angle of 90° with a 60-s rest between contractions. The higher torque of the two measures was used for further analysis.

Visual Analog Scale

The level of muscle soreness was quantified using a 100 mm VAS in which 0 indicated "no pain" and 100 represented "extreme pain". The subjects were asked to mark the level of perceived soreness on the VAS, when the elbow flexors were palpated in a circular motion by the investigator before and one, two, three and four days after exercise (24). During the palpation, the investigator placed his index and middle fingers over the mid-belly of the biceps brachii at 5, 9 and 13 cm above the elbow crease while the subject placed his forearm on an armrest that supported the elbow joint angle at approximately 90°. The investigator applied pressure [approximately 400 kPa] and palpated in a clockwise direction with the tips of the two fingers toward the deeper tissues at each site for approximately 3 s. The pressure [400 kPa] was based on our pilot study showing that this pressure induced pain when DOMS existed but not when DOMS was absent for most subjects, and it was close to the PPT for biceps brachii muscles for most subjects before exercise. The investigator practiced to reproduce the pressure, and it was confirmed that he could apply this pressure constantly. The palpation pressure given to the sites was kept as constant as possible between days and among subjects, and all measurements were taken by the same investigator throughout the experiment. The measurement at the 5 cm site was performed first followed by the measurements at the 9 and 13 cm sites in this order. One measurement was taken from each site with a 10-s interval between measurements. It should be noted that the arm length was not considered for the measurement sites, thus the relative distribution of the measurement sites was different among the subjects depending on the arm length in the present study.

Pressure Pain Threshold

After the VAS evaluation pressure pain threshold was measured using an electronic algometer [Somedic AB, Sweden] before, and one, two, three, and four days after exercise. The probe head of the algometer [area of 1.0 cm^2] was placed perpendicular to the mid-belly of the biceps brachii at 5, 9, and 13 cm above the elbow crease [the same sites as the palpation muscle soreness measures by VAS] and force was gradually applied at a rate of 50 $kPa \cdot s^{-1}$ until the subject reported the first feeling of noticeable pain of the muscle. The value [in kPa] corresponding to the force applied to elicit pain was recorded. In the same way to that of the VAS assessment, the 5 cm site was measured first followed by the 9 and 13 cm sites with a 30 s interval between measurements. Two minutes after completing the first round of the PPT assessment, the second round of the PPT assessment was performed in the same order and interval between sites. The average of the two measures for each site was used for further analysis.

Statistical Analyses

Changes in MVC torque over time were analyzed by a one-way repeated measures analysis of variance [ANOVA]. When the ANOVA showed a significant time effect, a Tukey's post-hoc test was followed for multiple comparisons. Changes in VAS and PPT over time were compared amongst the three measurement sites [5, 9, 13 cm] by a two-way repeated measures ANOVA. Pearson's product moment correlation coefficient was used to analyze the relationship between the VAS and PPT measures. A statistical significance was set as $P<0.05$, and all data were presented as mean ± standard error of mean [SEM], unless otherwise stated.

RESULTS

Reliability

Intra-class correlation [R] and coefficient variation [CV] were used to analyze the reliability of the VAS and PPT measurements using the data obtained from 10 subjects used in the study who had two pre-exercise measurements taken at one day prior to and immediately before exercise. The R of the intra-class correlation for 5, 9, and 13 cm sites ranged 0.98-0.99 for VAS and 0.92-0.98 for PPT, and the CV for 5, 9, and 13 cm sites ranged 2.2-4.5% for VAS and 5.6-8.9% for PPT.

MVC Torque

The baseline MVC torque was 55.5 ± 2.0 Nm. MVC torque decreased significantly [$P<0.05$] at one day post-exercise by approximately 40% to 32.9 ± 1.9 Nm, recovered to 71% of the pre-exercise level at three days [39.6 ± 1.9 Nm], and remained significantly [$P<0.05$] below the baseline by 23% at four days post-exercise [42.8 ± 2.0 Nm].

VAS

Figure 1 shows changes in VAS upon palpation of the biceps brachii muscle at the 5, 9, and 13 cm sites following eccentric exercise. The VAS significantly increased [$P<0.05$] after exercise and peaked at two days post-exercise. No significant [$P=0.62$] difference in the changes in VAS was evident among the three sites.

PPT

Changes in PPT at the 5, 9, and 13 cm sites are shown in Figure 2. No significant difference [P=0.87] in the pre-exercise PPT was found among the sites. The pressure to elicit pain decreased significantly [P<0.05] from the baseline [368.4 ± 23.7 kPa] to one day after eccentric exercise [262.7 ± 21.3 kPa], and remained significantly [P<0.05] below the baseline [328 ± 26.7 kPa] by 11% at four days post-exercise. No significant difference [P=0.45] in the changes in the PPT was evident amongst the three sites.

Correlation between VAS and PPT

Figure 3 shows correlation between the amount of changes in VAS and PPT at the 9 cm site at two days post-exercise from the baseline values. No significant correlations [r=-0.20, P=0.28] were found between VAS and PPT. No significant correlations were evident between the changes in VAS and PPT for other days [days 1, 3, and 4] and other sites [5 and 13 cm].

DISCUSSION

To the best of our knowledge, this is the first study to investigate the correlation between VAS and PPT for DOMS assessment of the elbow flexors after eccentric exercise. The results showed 1) no significant difference between the three assessment sites on the biceps brachii muscle [5, 9, and 13 cm above the elbow crease] for the changes in VAS and PPT following eccentric exercise, and 2) no significant correlation between VAS and PPT. Although some similarities exist for VAS upon palpation and PPT measurements, the time course of changes in VAS and PPT was different, and the changes were not correlated, thus the two forms of measurements appear to present different aspects of DOMS.

Both VAS and PPT have been widely used in previous studies (10,11,22) to quantify DOMS after eccentric exercise. The changes in VAS, PPT, and muscle strength after eccentric exercise in the present study were similar to those reported in previous studies (23,24) in which the elbow flexor eccentric exercise was performed in a similar way to that of the present study. Thus, the changes reported in this study are considered "typical" examples that are seen after eccentric exercise of the elbow flexors.

In the present study, DOMS assessments were taken from three sites on the biceps brachii muscle, which were assumed to represent the distal myotendinous junction [5 cm], mid-belly [9 cm], and proximal myotendinous junction [13 cm]. However, the chosen sites did not appear to be matched with the assumed region. It is important to note that the sites relative to the arm length were not the same amongst the subjects, and it was a limitation that the relative location of the sites was not considered in the present study. It should be noted that where in the biceps brachii muscle the sites, especially the 9 cm and 13 cm sites, were located was dependent on the arm length of subject. However, this does not appear to affect the analysis to compare between VAS and PPT, and that the results demonstrated no significant differences amongst the sites for VAS [Figure 1] and PPT [Figure 2].

Our recent study [unpublished data] showed that the most painful region of the biceps brachii muscle was located at the distal myotendinous junction following a similar eccentric exercise of the elbow flexors to that used in this present study. In the study, the whole surface covering the biceps brachii was divided into fifty regions by a grid method [5 x 10 matrix], and PPT of the 50 sites were assessed and compared. The difference in PPT between the regions that showed the highest sensitivity located at the distal myotendinous junction and other regions was 27–171 kPa [73.7 ± 5.3 kPa] at one day post-exercise and 9–162 kPa [52 ± 6.1 kPa] at two days

post-exercise. However, in the present study, there was no difference between the estimated distal myotendinous junction region [5 cm site] and other sites [9 and 13 cm sites]. It appears that the 5 cm region was not exactly the distal myotendinous junction site. In fact, more than 40 kPa difference existed between the most sensitive region [197.3 ± 20.2 kPa] and the regions surrounding the distal myotendinous junction in the 50 grid method with the range of 214–257 kPa [237.1 ± 5.7 kPa] in our recent study [unpublished data]. Thus, the 5 cm site did not appear to exactly match with the distal myotendinous junction. It seems likely that pain sensation of the biceps brachii is similar across the regions except for the distal myotendinous junction. It is necessary to identify the exact region corresponding to the distal myotendinous junction and include it in the pain assessment following eccentric exercise of the elbow flexors in future studies.

It should be noted that the time course of change in the VAS and PPT was different following eccentric exercise, such that muscle soreness assessed by VAS peaked two days post exercise [Figure 1], but the reduction of PPT was greatest at one day post-exercise [Figure 2]. This was also reported in previous studies from other laboratories (11,22) and in our previous studies (23,24). For example, Rice et al. (22) reported that muscle soreness assessed by VAS significantly increased at one day and peaked at two days after exercise, but PPT significantly decreased at one day post-exercise and no further change was seen at two days following four sets of 15 eccentric and concentric contractions of the knee extensors. Peake et al. (23) showed that muscle soreness assessed by VAS peaked at two days post-exercise, but PPT decreased at one day post-exercise, and no further decrease was evident at two days post-exercise following 10 sets of three eccentric contractions of the elbow flexors. However, there was no discussion in these studies as to why the time course of the changes was different between VAS and PPT.

It is speculated that the different time course between VAS and PPT is associated with the different ways to quantify pain sensation. It is important that the minimum pressure to induce pain is assessed in PPT measurements, whereas the magnitude of pain felt with a standardized pressure is assessed in VAS measurements [approximately 400 kPa in the present study]. It is assumed that PPT decreases with the development of DOMS; however, it is possible that the threshold to feel the "first discernible sensation of pain" in the muscle does not decrease further, even if the magnitude of the pain to a standardized pressure increases. It should also be noted that the subjects rated the magnitude of pain using VAS after the muscles were palpated by the investigator who placed his index and middle fingers over the biceps brachii muscle and moved the muscles in a circular motion for 3 s. We have found [unpublished data] that palpating the muscle during DOMS induces greater pain than only applying a static pressure with the tips of the fingers toward the deeper tissues. Thus, it may be that the time course of changes in DOMS is better represented in VAS than PPT.

The present study showed no significant correlation between VAS and PPT [Figure 3]. Although both measurements used "pressure" to induce pain, there are some differences the measurements. As discussed above, PPT assessment is a single point method that detects the pain threshold by applying a minimum stimulus intensity to perceive a painful sensation (6). The pain sensation of PPT depends on the stimulus intensity or the duration of time corresponding to a fixed response to pain threshold; therefore, this method is considered to be a stimulus-dependent method (25). However, VAS is a supra-threshold pain intensity rating method to detect the pain intensities by a standardized stimulus (6). Since this method includes sensations over the whole perceptual range and does not detect only a single point of the threshold level, subjects can quantify the evoked pain sensation on the scale, and this rating method is classified as a

response-dependent method (25). It can be said that PPT detects a pain threshold for “minimum stimulus intensity”, but VAS represents pain intensity through “subject responses to a whole perceptual range of pain intensity” (25).

It is also important to point out that the interval between assessments was different between VAS and PPT in the present study. The interval for the VAS assessment between sites was 10 s, but the interval between sites in the PPT assessment was 30 s. Ruscheweyh et al. (26) reported that pain perception was reduced by three different distraction strategies (i.e. two minutes of mental imagery, music and brush tasks), and pain reduction was due to descending pain inhibition. It is possible that the longer interval (30 s) between measures in the PPT assessment resulted in different pain perception than that in the VAS assessment that used a shorter interval (10 s) between measures. It would have been better to match the interval time between the VAS and PPT measures. However, Nie et al. (27) investigated the temporal summation of pressure pain during four (1, 5, 10 and 30 s) different inter-stimulus intervals (ISI) over ten sequential pressure stimulation after induction of DOMS of the trapezius muscle, and found that 1 s stimulus duration showed significant higher VAS scores than 5, 10, and 30 s ISI, but no significant difference among 5, 10 and 30 s. Therefore, it seems unlikely that the different measurement intervals between the VAS (10 s) and PPT (30 s) assessments can fully explain the no significant relationship between the two measures shown in Figure 3.

In the present study, the stimulated area for VAS assessment [index and middle fingers] was approximately 3 to 4 cm^2, whereas the head of the probe for PPT assessment was 1 cm^2. Andersen et al. (28) suggested that using a larger stimulated area [probe] to detect muscle pain threshold could reduce the cutaneous sensitization during measurement because the pressure is spread over a larger area on the tissue. Previous studies (16,29) found that increasing the size of

the stimulated area could increase the pain thresholds detected from the skin or from the deep tissue such as muscle and fascia. Thus, it seems that a larger stimulated area in VAS affected more nociceptors than PPT. It is possible that the movement in the VAS assessment not only stimulates a larger area of the muscle at the specific measurement site, but also stimulates the surrounding tissue including skin, connective tissues, and muscles; stimulating more nociceptors and changing the sensitization of the dorsal horn neurons of the spinal cord. Nie et al. (27) reported that 1 s of sequential suprathreshold stimuli facilitated temporal summation of pressure pain on sore muscle. It is possible that the suprathreshold stimuli during VAS assessment enhanced dorsal horn temporal summation, whereas the stimuli applied during PPT assessment did not have such an effect. Further studies are necessary to understand the underpinning mechanisms of DOMS, and how the mechanisms are associated with the difference in VAS and PPT.

In conclusion, the present study has shown that muscle pain assessed by VAS upon palpation and PPT is different. This indicates that VAS and PPT assessments represent different aspects of pain. Therefore, it is better to include both VAS and PPT to assess DOMS; however, if it is necessary to choose one method of assessment, once the protocol of the VAS measure is carefully standardized, VAS would indicate the time course of changes in DOMS more accurately than PPT.

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FIGURE LEGEND

Figure 1: Changes [mean ± standard error of mean] in visual analog scale [VAS] upon palpation on three sites [5, 9, and 13 cm] before [pre] and 1 to 4 days following eccentric exercise. # = significant [$P<0.05$] difference from the pre-exercise value, n.s. = not significantly different among the groups.

Figure 2: Changes [mean ± standard error of mean] in pressure pain threshold [PPT] of biceps brachii muscle at three sites [5, 9, and 13 cm] before [pre] and 1 to 4 days following eccentric exercise. # = significant [$P<0.05$] difference from the pre-exercise value, n.s. = not significantly different among the groups.

Figure 3: Correlation between visual analog scale [VAS] and pressure pain threshold [PPT] at 9 cm site measured at two days post-exercise. n.s. = no significant correlation

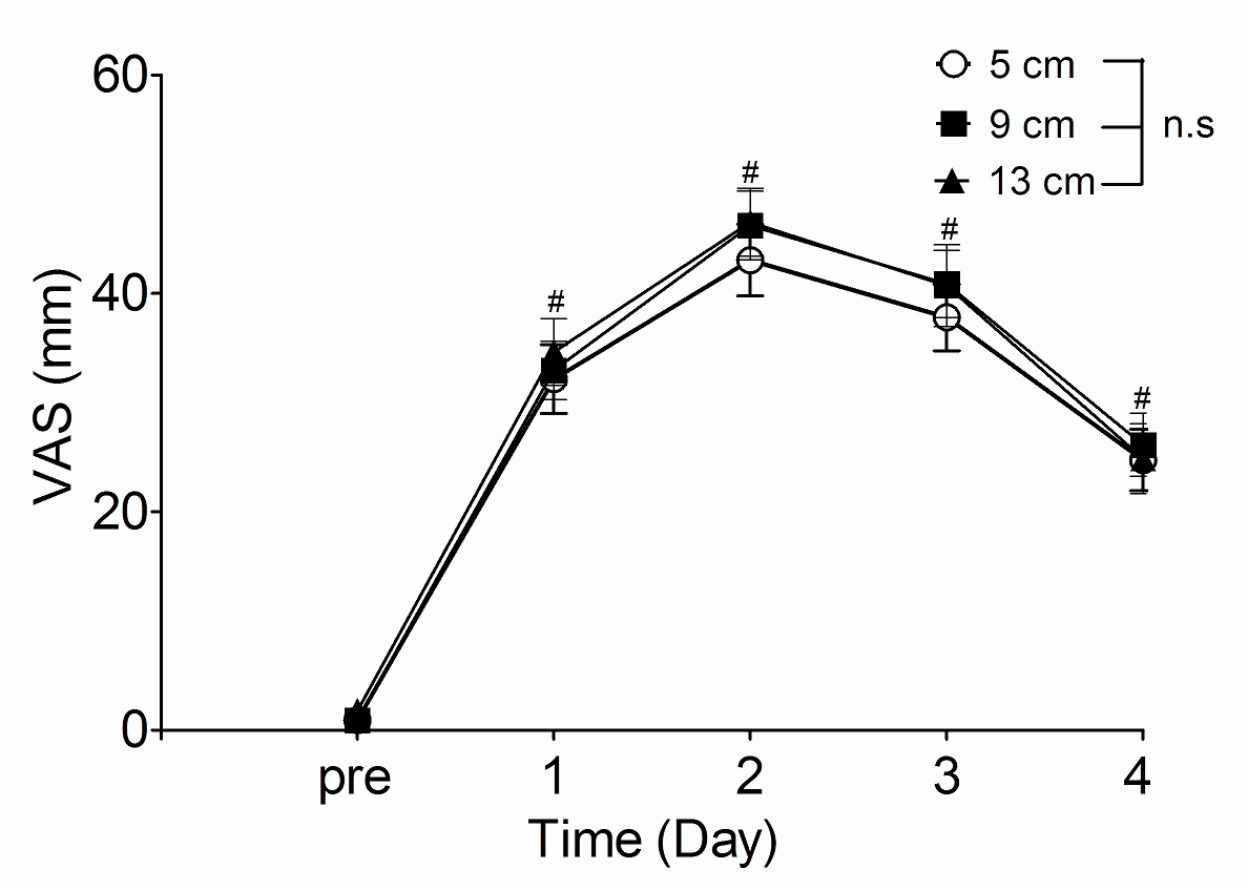

Figure 1.

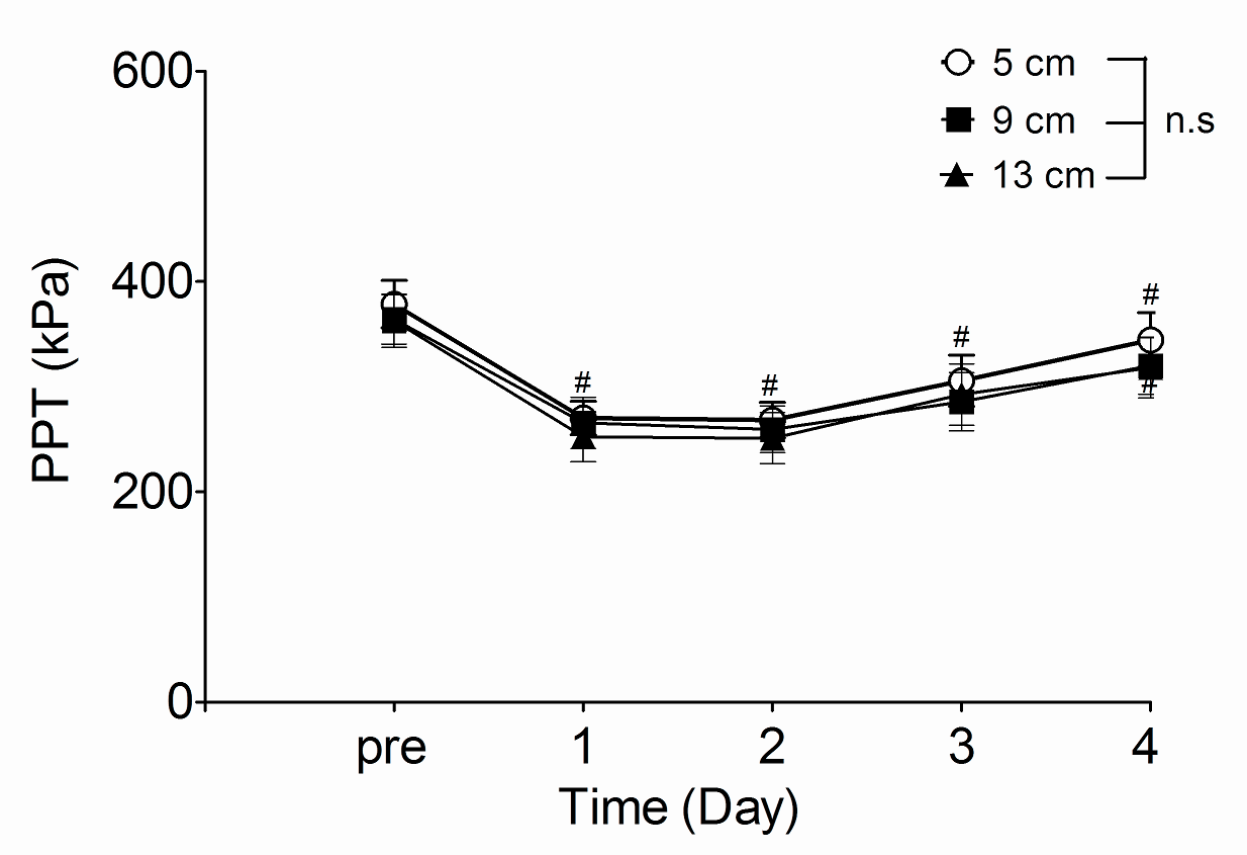

Figure 2.

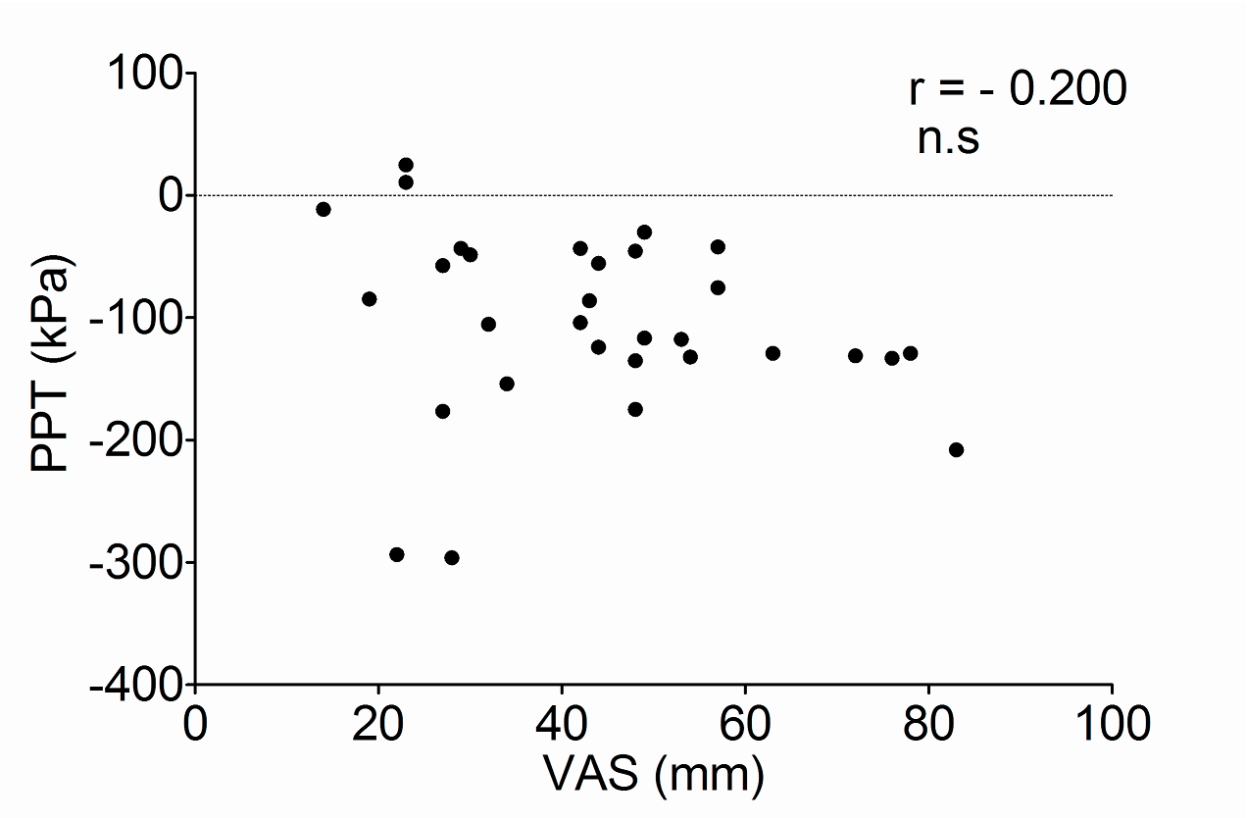

Figure 3.