Title: Pain-Induced Impact on Movement: Motor Coordination Variability and Accuracy-Based Skill

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Abstract

Studies on pain are generally conducted for two purposes: first, to study patients with pain who have physical changes due to nerve and muscle lesions, and second, to regain the appropriate kinematic post-pain pattern. The present study aimed to investigate the effect of pain on the coordination variability pattern and throw accuracy. Participants included 30 people with a mean age of 18-25 years who volunteered to participate in the study. Individuals were randomly divided into three groups of local pain, remote pain, and control group. Without pain, participants practiced and acquired skills in 10 blocks of 15 trials. In the retention and transition phase, which were associated with pain, in their respective groups, included 1 hour, 24-hour, and 1-week acquisition; they were re-tested twice in a 15-block trial, which was once with and without pain. The results revealed that pain did not affect the throwing accuracy (\( p = 0.469 \)). Besides, in the phase of decreasing acceleration in throwing, movement variability pattern in the pain-related groups in the shoulder and elbow joints (\( p = 0.000 \)), elbow and wrist (\( p = 0.000 \)), were more than the painless groups. Based on the results, it can be said that the increase in variability in pain-related groups is due to the different strategies and patterns that individuals use to avoid pain. Also, despite the pain, the nervous system attempts to increase the variability find the least painful pattern of movement and reduces this variability over time and using a repetitive pattern.

**Keywords:** Local pain; Remote pain; Coordination variability pattern; Motor skill; Throw accuracy
1. Introduction

Individuals who experience pain, show poor motor results, and have also been shown to have a more limited ability to learn motor patterns (1). Human and animal studies have shown that pain can affect motor pathways (2), and researchers have found that pain can reduce the contractile volume and reduce muscular endurance and alter motor coordination during dynamic motor tasks (3, 4, 5). In general, studies have demonstrated that spinal cortical inhibition in the presence of pain may interfere with normal and immediate muscle function, and this event may impair the motor cortical plasticity potential (6). Most individuals' performance, such as speed and accuracy, is affected by pain, and pain adaptation involves changes in several levels of the somatosensory system (7).

Studies on pain are generally carried out for two purposes: first, to study patients with pain who have physical changes due to nerve and muscle lesions, and second, to regain the appropriate kinematic pattern after pain (8). Different theories have suggested responses and adaptations to pain, but in general, there are different patterns for adapting to pain and empirical responses to pain that differ from one person to another and from one task to another. Research observations show that muscles change the way they produce energy and the strategy of movement instead of inhibiting activity (7). Pain-adaptation theory has shown these changes as redistribution of intramuscular activity, motor mechanisms, movement modification, and muscle contraction, and pain and injury protection mechanisms (7). The argument is that in the presence of pain, the active units change and lead to changes in muscle strength and muscle movement direction (7). Since
the pain restriction is ordinarily joint, the body compensates by increasing movement in other parts of the body (9).

The central nervous system has different strategies for performing each functional task, and ideally, the CNS selects the most appropriate and least risky strategy for pain and chooses the least painful and appropriate pattern by coordinating the synergies of an organ or general pattern (10). Variability is a significant feature of most neuropathic and musculoskeletal pain and is essential in the diagnosis and classification of imperfect movements for therapists and for the effective monitoring of symptoms by controlling incomplete movements (11). Bergin (2016) suggests that reducing variability during acute pain in a short time may help achieve the safety goals of the nervous and motor systems, but maintaining it, in the long run, may interfere with the full and correct execution of the movement (12). Therefore, it is necessary to conduct such research in this area to show the muscular and motor changes under the influence of pain and what changes these changes under the learning of skills. Ultimately, this research could lead to the development of practical exercises to recover from the pain and obtain an appropriate movement pattern.

There are conflicting results in studies of variability in acute and chronic pain. Moseley (2006), (13) and Madeleine (2008), (14) stated that variability increases when there is acute pain, while some researchers have stated that variability decreases during chronic pain (15, 16, 17). However, when there is chronic pain due to adaptability, the variability that increased at the beginning of the movement may decrease with continued movement and exercise. In the presence of acute pain in individuals due to incompatibility, variability faces a steady decline or increase (12).
Besides, several researchers have stated that the variability in the motor system depends on the location and the type of pain (18). Depending on the pain's location, there are conflicting results in reducing or increasing variability in the movement system (18). This reduction in variability is likely due to a reduction in error and control of damaged joints and organs (19). On the other hand, depending on the location of the pain and the type of task, the motor system may use another strategy that combines reducing the variability in the affected limb and increasing the variability in the parts of the body that are painless (12). In this context, increasing variability may be a strategy to compensate for less movement in painful limbs and joints and maintain the overall movement pattern (20). Studies have shown that people with pain variability reduce their coordination, and as a strategy to reduce pain, this strategy can increase pressure on an area and muscle pressure and lead to new injury (21). It is assumed that as a result of a change in the activity of the response or avoidance of pain response, in the face of painful stimuli, the variability in movement decreases (22). This reduction in variability indicates a decrease in the motor system's flexibility, in which people use less common patterns and movement sections to produce movements (23). Less use movement patterns and less moving parts in coordination variability in people, who experienced pain, may indicate that people are trying to avoid pain or are unable to obtain a full range of motion patterns due to pain and injury (24). In injured people or those with a history of injury, the variability of coordination changes over a short period, which is only due to excessive pressure on the use of a pattern and muscle fatigue (25).

In the presence of less pain, individuals can integrate the relationship between stages or the coordination of parts of the body (26). In 2005, Lamoth et al. showed that people with low back pain (LBP) symptoms showed a significant reduction in the coordination
variability and the step-by-step steps in the trunk and hip joint (25). In another study, comparing healthy and painful people's patterns of coordination showed that healthy people during walking and rotation, first, the pelvic oscillation and in the middle of the way the body rotates in the opposite direction and the final stage the joints rotate in one direction (26). However, in individuals with pain, this rotations distinction between limbs could not be observed, which may be due to increased stiffness of the trunk muscles and decreased coordination (27). These changes are useful in interrelated and ongoing stages and are used to differentiate between healthy and pain-experienced individuals associated with reduced variability in people with pain (28).

However, previous studies have provided crucial information and insights about variability and execution accuracy in the presence of pain. Nevertheless, gaining a profound understanding of this and helping clinical rehabilitation in people with the pain while still moving, requires further study to show what changes in the pattern of movement coordination variability, despite the acute pain, over time occur, also, with the passage of time and the persistence of pain in individuals, what changes the pattern of coordination and accuracy of execution have.

Materials and Methods

2.1 Participants

Thirty males aged 18-25 years who were all right-handed and had no knowledge of dart-throwing skills volunteered to participate in the present study. Participants were randomly divided into three groups of local pain, remote pain, and control group. The inclusion criteria for this study were: Right-handedness, no history of illness, not being an athlete,
no education in physical education, no experience in dart-throwing, and no experience of acute and chronic pain with scale 7 in the right hand and right foot. All participants were homogenized in terms of age, level of education, geographic area of life, height, and weight. Also, all experiments were approved by the Research and Ethics Committee of Shahid Beheshti University (IR.SBU.ICBS.97/1046), Tehran, Iran.

2.2 Data Collection Tools
The learning and the throwing accuracy were measured using the dartboard and the participants’ scores during the two acquisition and retention phases. In the present study, the ordinary circular-shaped dartboard made of compressed paper, with a diameter of 159 mm and a thickness of 12 mm, and for throwing the backboard of the dartboard, which numbered from zero to ten, was used. According to the World Darts Federation's instructions, the dartboard mounted with the center of the bullseye at the height of 1.73 m from the floor in the laboratory. A line was drawn on the floor at a distance of 2.37 m from the dartboard that at the time of throwing, the subjects' feet were behind the throw line. Fifteen metal darts tips with a 25-gram weight and a 15-cm length for throwing were used.

Human Motion Analysis Machine. An American-made motion analysis model, was used to record the kinematic motions. This motion picture camera powered by eight infrared cameras at 240 frames per second. Cortex software was also used to analyze motions. In order to obtain accurate and noise-free data, the test environment must be calibrated. For this purpose, after arranging the cameras and adjusting the height and field of view of the cameras according to the volume of the test environment and the height of the participants, first the static caliber and then the dynamic caliber were performed. After
three-dimensional calibration (static and dynamic), the spatial accuracy of the system should be less than 0.03 mm. At this point, after defining and naming the markers, as well as specifying the time of movement, the video recording phase began.

**Markers.** To achieve the kinematic characteristics of movements using an imaging device, the peculiarities of specific parts of the body must be specified. To this end, spherical light-reflecting markers are mounted on the bony prominence limbs, which are often equivalent to or close to the joint axis of movement. Eleven markers on participants' body including right acromion, the middle part of the humerus, lateral and medial humeral epicondyles, the middle part of the Forearm, radial and ulnar styloid processes, middle of the third metacarpi, distal extremity of the second and fifth metacarpi. A marker attached as a reference in the trunk area, beneath the prominence of the last rib cage.

**Movement coordination variability.** Various methods have devised in quantifying coordination, which in the present study, due to the type of tasks and assumptions, the vector coding method used to measure coordination variability. Vector coding techniques have been introduced the data in relative motion plots and the variability in angle-angle trajectories (29). These techniques stem from the early work of Freeman (1961), who devised a chain-encoding technique to quantify an angle-angle curve (30).

**Visual Analogue Scale (VAS).** VAS is the pain measurement instrument scaled from zero to ten, includes a horizontal line ranged from zero to ten in which zero indicates “no pain at all” and ten represents “pain as bad as it could be” (31). Capsaicin 1% gel was used to induce pain, which contains red pepper and stimulates free nerve endings and pain receptors.
2.3 Implementation Procedures

Participants were selected from healthy individuals with no history of illness and muscle pain and no experience in dart-throwing. All participants were volunteers and informed consent given for applying the pain. In this test, the application of pain in the transition phase was learned to investigate the effect of pain on the coordination pattern variability of a task and movement accuracy. Before conducting the research, participants were asked to perform 15 throwing trials as a baseline and a pre-test. In the implementation phase, participants were first introduced to the basic principles of dart-throwing skills, such as the way of the gripping dart and how to score. The researcher then demonstrated the dart-throwing skill pattern to all participants in each group three times separately. Individuals performed the movement during 15 throws, which was considered a basic level, as well as a pre-test of individuals.

Participants were divided into three groups, including local pain, remote pain, and control group. In the acquisition phase, participants practiced and acquired skills in 10 blocks of 15 attempts without pain. Participants were placed on the launch line after a 5-minute warm-up phase and then began throwing. At each stage, five darts were thrown, and then participants rested for 1 minute while collecting arrows from the dartboard. After performing the pre-test and practicing 150 trials, they were evaluated in three phases of retention and transition tests. In the retention and transition phases, changes in the underlying conditions of individuals’ skills were associated with pain. Participants in their respective groups, in three phases, including 1- hour, 24- hour, and 1- week acquisition, were twice re-tested in a 15-block trial, under any circumstances, once without pain and once with pain.
In local pain, capsaicin gel is applied to the outer side of the elbow five cm, and in remote pain, capsaicin gel to the upper area of the knee joint is five cm. The amount of pain was measured using the VAS scale. Movements in pain groups were performed when individuals reported the severity of their pain perception of seven. In all stages of trial and retention tests, the pain-free control group was evaluated. Also, the control group was tested as a placebo by using Methyl salicylate gel under transition condition, which only feels local heat and is painless, under the same conditions as the other groups (Fig. 1).

2.4 Motion Phases

Dart-throwing motion consists of four phases: aiming, take-back, acceleration, and deceleration and release. The aiming phase involves focusing on the target, which will continue with the backward movement of the elbow that performs the elbow flexion motion. At the end of this phase, the velocity of the limb and elbow joint becomes zero. The onset of the acceleration phase is associated with a reversal from flexion to elbow extension. At the end of this phase, the hand reaches the deceleration and release phase. In the present study, motion analysis is focused on the acceleration and deceleration and dart release phase (flexion to elbow extension).

2.5 Data Collection

In order to record accurate and noise-free data, the test environment must be calibrated. For this purpose, the system's spatial accuracy must be less than 0.03 mm, and a 10Hz double-sided Butterworth filter was used to cut and divide the frequencies equally into three to smooth the data. After processing operations in Cortex software, the data to
calculate kinematic variables in Excel format extracted. In this study, maximum wrist flexion range, maximum elbow extension range, shoulder angular displacement range, angular throw velocity, and throw duration are considered pattern kinematic variables. The joint motion range was considered as the difference between maximal flexion and maximal extension of each joint. Throw time was calculated by the difference between the moment of movement start (maximum elbow flexion) and the moment of movement end (maximum elbow extension). The angular velocity of the throw was also obtained by dividing the angular displacement range of the elbow by the throw time.

3. Results

The statistical method of the present study was to investigate the effects of pain in four phases of the combined analysis of variance tests (3×4). The Shapiro–Wilk test for normality of the data and the Levene’s test for variance equality were also used. During skill acquisition, pain intensity was not significantly different between the two groups (p = 0.783; Supplementary Table 1). Fig. 2A shows the evolution of the perceived pain intensity across the 10 training blocks.

3.1 Throwing Accuracy

The combined variance analysis test (3×4) indicated that there was no difference in throwing accuracy between people with pain and without pain and the main effect of the group (F = 0.779, p = 0.469, eta = 0.055) was not significant. Also, over time, there was no difference between the groups in terms of throwing accuracy, and the main effect of the measurement steps (F = 5.06, p = 0.297, eta = 0.37) was not significant. In addition,
the interactive effect of group and evaluation steps (F = 0.61, p = 0.148, eta = 0.21) is not significant (Fig. 2B). Bonferroni post-hoc comparisons on the significant evaluation phase’s effect showed that there was significant difference between pre-test and 1 hour later (p=0.008), pre-test and 24 hours later (p=0.025). There is also no significant difference between evaluation times (Fig. 2B).

The results demonstrated that the throwing accuracy of all groups did not differ in pain-free mode (F = 0.593, p = 0.624, eta = 0.049). Also, over time, there was no difference between the groups in terms of throwing accuracy, and the main effect of the measurement steps (F = 3.75, p = 0.357, eta = 0.37) was not significant. In addition, the interactive effect of group and evaluation steps (F = 6.61, p = 0.379, eta = 0.21) is not significant (Fig. 2C). Bonferroni post-hoc comparisons on the significant evaluation phase’s effect showed that there was significant difference between pre-test and 1 hour later (p = 0.012), pre-test and 24 hours later (p = 0.006), and pre-test and one week later (p = 0.021). There is also no significant difference between evaluation times (Fig. 2C).

3.2 Coordination Pattern Variability

3.2.1 Acceleration phase

The combined variance analysis test (3×4) for shoulder - elbow coordination pattern variability showed that individuals with local and remote pain and, pain-free did not differ in three phases of the test (F = 0.236, p = 0.791, eta = 0.018). Also, by examining the evaluation phases (F = 0.611, p = 0.615, eta = 0.071) and the interactive effect of the group and the evaluation phases (F = 0.319, p = 0.924, eta = 0.038), the results showed that the statistical difference was not significant (Fig. 3A). Bonferroni post-hoc comparisons on the significant evaluation phase’s effect showed that there was significant
difference between pre-test and one week later (p = 0.001). There is also no significant difference between evaluation times (Fig. 3A).

The results also showed that the coordination pattern variability of shoulder - elbow in the three pain-free groups was not statistically significant (F = 0.416, p = 0.534, eta = 0.023). Also, over time, there was no difference between the groups in terms of throwing accuracy, and the main effect of the measurement steps (F = 4.19, p = 0.193, eta = 0.24) was not significant. In addition, the interactive effect of group and evaluation steps (F = 3.83, p = 0.764, eta = 0.34) is not significant (Fig. 3B). Bonferroni post-hoc comparisons on the significant evaluation phase’s effect showed that there was significant difference between pre-test and 1 hour later (p = 0.009), pre-test and 24 hours later (p = 0.014), and pre-test and one week later (p = 0.018). There is also no significant difference between evaluation times (Fig. 3B).

The combined variance analysis test (3×4), showed that participants with pain were not statistically significant different from those in the group without pain in coordination pattern variability of elbow - wrist (F = 8.979, p = 0.656, eta = 0.032). Besides, in evaluation phases (F = 1.458, p = 0.244, eta = 0.157), and also due to group interaction and evaluation steps (F = 0.693, p = 0.656, eta = 0.080) no significant statistical difference was observed (Fig. 4A).

The results also showed that the coordination pattern variability of elbow - wrist in the three pain-free groups was not statistically significant (F = 0.854, p = 0.437, eta = 0.19). In evaluation phases (F = 0.572, p = 0.571, eta = 0.042), and also due to group interaction and evaluation steps (F = 2.323, p = 0.101, eta = 0.225) no significant statistical difference was observed (Fig. 4B).
3.2.2 Deceleration and dart drop phase

The combined variance analysis test (3x4) showed that participants with local pain had more shoulder-elbow coordination variability than those without pain. Also, individuals with remote pain indicated coordination variability than the pain-free group. However, there was no statistically significant difference between local pain and remote pain (F = 27.819, p = 0.000, eta = 0.682). In the evaluation phases in all three groups, a statistically significant difference was observed that over time the difference between people with local pain and remote pain decreased (F = 4.981, p = 0.008, eta = 0.384) and the interactive effect of the group and evaluation phases (F = 3.908, p = 0.003, eta = 0.328) were also significant (Fig. 5A). The results of the Bonferroni post-hoc showed that there was a significant difference between local pain and control groups (p = 0.006) and there was a significant difference between group Remote pain and control (p = 0.001). In addition, The results of the Bonferroni post-hoc of the evaluation steps also indicate that there is significant difference between the pretest time and 1 hour later (p=0.014), and between the pre-test time and a week later (p=0.001) there is a significant difference (Fig. 5A).

Also, the groups’ results during the painless retention tests showed that all individuals did not have any statistically significant difference in the shoulder - elbow coordination variability (F=27.661, sig=0.237, eta=0.480). In the evaluation phases in all three groups, a statistically significant difference was observed that over time the difference between people with local pain and remote pain decreased (F= 0.172, sig=0.975, eta=0.009) and the interactive effect of the group and evaluation phases (F=3.363, sig=0.098, eta=0.296) were also significant (Fig. 5B). Bonferroni post-hoc comparisons on the significant evaluation phase’s effect showed that there was significant difference between pre-test
and 1 hour later (p = 0.027), pre-test and 24 hours later (p = 0.034), and pre-test and one week later (p = 0.046). There is also no significant difference between evaluation times (Fig. 5B).

The combined variance analysis test (3x4) indicated that individuals with local and remote pain had more coordination variability than the control group. Also, people with local pain had more elbow - wrist coordination variability (F = 26.247, p = 0.000, eta = 0.669). In addition, in the evaluation phases (F = 0.373, sig = 0.043, eta = 0.045), as well as the interactive effect of the group and evaluation phases (F = 2.478, sig = 0.036, eta = 0.237), the results are not significant (Fig. 6A). The results of the Bonferroni post-*hoc* showed that there was a significant difference between local pain and control groups (p = 0.012) and there was a significant difference between group Remote pain and control (p = 0.004) In addition, The results of the Bonferroni post-*hoc* of the evaluation steps also indicate that there is no significant difference between Evaluation steps (Fig. 6A).

In three phases of pain-free retention test in three groups, individuals reduced the coordination variability of the elbow - wrist movement and no statistically significant difference was observed between groups (F = 2.412, p = 0.141, eta = 0.332) in the evaluation phases (F= 0.652, p= 0.590, eta=0.075), as well as the interactive effect of the group and evaluation phases (F=2.108, p= 0.169, eta=0.209), the results are not significant (Fig. 6B). Bonferroni post-*hoc* comparisons on the significant evaluation phase’s effect showed that there was significant difference between pre-test and 1 hour later (p = 0.014), pre-test and 24 hours later (p = 0.035), and pre-test and one week later (p = 0.027). There is also no significant difference between evaluation times (Fig. 6B).
4. Discussion

The present study was conducted to investigate the pain-related impact on the accuracy and the coordination variability pattern in the acquire skill in tasks. The results revealed that the pain did not affect the throwing accuracy learned, but increased the deceleration and dart drop phase variability. Based on the obtained results, it can be stated that the increase in variability in pain-related groups is due to the various strategies and patterns that individuals use to avoid pain.

In general, the pain did not affect individuals’ overall performance. Pain-related research in the retention period is used to evaluate the central nervous system's adaptability and to strengthen the movement pattern. However, according to the results of Bouffard (2014), adaptation to pain causes changes in retention and transition skills. Accordingly, it can be stated that each person can use a unique strategy during the stage of adaptation to pain due to the level of pain perception and endurance of individuals, while the goal of the movement is the same in all individuals (8). Also, depending on the location and type of pain, people can use more or less various parts of their limbs, and this leads to an increase or decrease in the variability (14). When using complex and multi-joint tasks in the presence of pain, the nervous system tries to reduce pain by using a solution and variable options in the limbs to perform the motor function, which may increase motor function (13).

The present study’s results show that although individuals with pain increase their coordination variability, the accuracy of throwing and achieving the goal of movement in these people was not different from painless individuals. These results are in line with Ingham's study, which found that people achieved their goal of movement despite the
pain (32). However, some previous studies have shown a lack of overall goal achievement in persons with pain (33, 34), which is inconsistent with the results of the present study and seems to be due to the use of different tasks.

On the other hand, some studies have shown that the type of pain is also useful in increasing or decreasing the individuals’ coordination variability (35). Two studies, Hamill 1999 and Heiderscheit 2002 showed that people in chronic pain show a decrease in the movement pattern variability to get rid of pain (15, 36). However, in people with acute pain, the nervous system at the beginning of the movement shows an increase in the variability of the main components of the motion and then a decrease in these components and an increase in the use and consequently, the variability in the non-primary motion (11). The results of the present study are in line with the study of Moseley and Hodges, in which initially the coordination variability increased and over time, the variability in the central organ of movement decreased (13).

According to Bergin's research, pain can lead to the overuse of unnecessary organs, which increases variability, consistent with the results of the present study (12). Besides, in her study, Madeleine concluded that pain increases variability in limbs that are consistent with the results of the present study (14). Previous research has shown that restructuring muscle activity or kinematic changes in individuals with pain increases variability in movement strategies, but the overall goal of skill will be maintained (10).

During the learning of the skill, based on the training feature's hypothesis, individuals’ performance will be disrupted by changing the training ground. According to this theory, by manipulating the input and output information to the nervous system involved in controlling movement, individuals’ performance will be disrupted and changed (37). According to studies, the use of pain can cause different spinal cord stimuli and the
nervous system involved in controlling movement. The presence of pain also impairs cortical mapping and impairs motor function (38).

The present study results revealed that the accuracy of people in the presence of pain did not change, and there was no difference between the throwing accuracy in people with pain and without pain. When the pain-free retention test was taken, there was no difference in the accuracy and variability of individuals in the groups. In the transition tests, despite the pain, the individuals were placed in different training conditions, there was no difference in the throwing accuracy between the individuals in the pain and pain-free groups. Due to the use of pain in different organs, the researcher sought to investigate the effects of local pain and remote pain in the throwing accuracy. The results showed that the pain’s location did not affect the throwing accuracy, consistent with the Bilodeau’s results (39). However, Dancey (2016) concluded in his research that local pain causes more attention to movement and improves accuracy, and remote pain causes distraction and reduces the individuals’ accuracy, which is inconsistent with the results of the present study (18).

5. Conclusion

The present study showed that pain does not affect the throwing accuracy and achieving goals, but it is useful in changing the coordination pattern variability and increases the coordination variability of the limbs. Over time and with pain adaptability, this variability decreased slightly. Based on the present study results, it seems that the nervous system, despite the pain, tries to increase the variability in the components of movement to find the least painful pattern of movement and, over time, using a repetitive pattern reduces
this variability. A significant study in the selection of pain movement strategies includes multiple factors to reduce and prevent further tissue damage. Some of these factors increase and some decrease, including the starting and ending points of the skill and the amount of energy and strength that a muscle uses effectively, as well as the sequence and muscles used in the movement.
References


**Figure legend:**

**Fig. 1:** Experimental design

**Fig. 2.** (A) The average intensity of pain in two groups of localized pain and away from the position in three transition tests. (B & C) The average score of throw accuracy at four times: pre-test, 2 hours (immediate), 24 hours, and one week (delayed). Black circle with dot marker, Average throw accuracy score in the control group. Square with Stripe, Throw accuracy in local pain group. Gray triangle with line, Average accuracy in remote pain group. Diacritic marks (*) indicate significant differences (p<0.05) between the three stages of evaluation and pre-test.

**Fig. 3:** Mean score of Coordination variability of shoulder to elbow in acceleration phase at four time points: pre-test, 1 hour (immediate), 2 hours and 1 week (delayed). In Figure A, the pain test and in Figure B, the groups are painless. That Black circle with dot marker Coordination variability of shoulder to elbow in acceleration phase in control group, Square with Stripe Coordination variability of shoulder to elbow in acceleration phase in local pain group, Gray triangle with line Coordination variability of shoulder to elbow in acceleration phase in remote group. Diacritic marks (*) indicate significant differences (p<0.05) between the three stages of evaluation and pre-test.
**Fig. 4**: Mean score of Coordination variability of elbow to wrist in acceleration phase at four time points: pre-test, 1 hour (immediate), 2 hours and 1 week (delayed). In Figure A, the pain test and in Figure B, the groups are painless That Black circle with dot marker Coordination variability of elbow to wrist in acceleration phase in control group, Square with Stripe Coordination variability of elbow to wrist in acceleration phase in local pain group, Gray triangle with line Coordination variability of elbow to wrist in acceleration phase in remote group.

**Fig. 5**: Mean score of Variability of wrist flexion in acceleration phase at four time points: pre-test, 1 hour (immediate), 2 hours and 1 week (delayed). In Figure A, the pain test and in Figure B, the groups are painless That Black Column Variability of wrist flexion in acceleration phase in control group, Bold gray column Variability of wrist flexion in acceleration phase in local pain group, Pale gray column Variability of wrist flexion in acceleration phase in remote group. Diacritic marks (*) indicate significant differences (p<0.05) between group control and Local and Remote pain, Also significant differences (p<0.05) between the three stages of evaluation and pre-test.

**Fig. 6**: Mean score of Shoulder - elbow coordination variability in deceleration and dart release phase at four time points: pre-test, 1 hour (immediate), 2 hours and 1 week (delayed). In Figure A, the pain test and in Figure B, the groups are painless That Black circle with dot marker Shoulder - elbow coordination variability in deceleration and dart
release phase in control group, Square with Stripe Shoulder - elbow coordination variability in deceleration and dart release phase in local pain group, Gray triangle with line Shoulder - elbow coordination variability in deceleration and dart release phase in remote group.

Diacritic marks (*) indicate significant differences (p<0.05) between group control and Local and Remote pain. Also significant differences (p<0.05) between the three stages of evaluation and pre-test.