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# The effect of Soft Tissue Manipulation and Rest on Knee Extensor Muscles Fatigue: Do torque Parameters and Induced Perception Following Muscle Fatigue Have Enough Reliability?

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# Abstract

Background The aim of the study is comparison of the effects of soft tissue manipulation and rest on the knee extensor muscle fatigue after maximal isokinetic contractions. Methods Fifteen healthy females aged 20-30 years selected for research. This study implemented a semi-experimental test-retest measurement method. Each of the volunteers was evaluated three sessions. The first session was to familiarize the volunteers with the test and isokinetics. For the main test, each of the volunteers was evaluated twice with a one-week interval between evaluations. In each session, after warm-up, perceived fatigue using a visual analog scale (VAS), average of peak torque (APT), and average power (AP) for maximal concentric isokinetic output of the quadriceps was measured at a velocity of 60 degrees per second. Then¸ in order to apply the fatigue protocol, the subjects were asked to perform successive maximal quadriceps contractions until three consecutive quadriceps torque outputs reached below 50 percent maximal torque output. Afterwards, for remeasurement, the average of peak torque and average power were calculated. The extent of perceived fatigue was evaluated as before. Subjects then either rested or received soft tissue manipulation on the knee extensors for a 15-minute duration. After intervention (soft tissue manipulation or rest) parameters were evaluated for third time. Results The stability of average peak torque¸ average power, and visual analog scale before performing fatigue protocol was 85%, 83%, and 31.9%, respectively. The stability after fatigue was 43%, 50%, and 93%, respectively. After maximal fatigue and a decrease in torque output to below 50 percent maximal torque, 15 minutes of soft tissue manipulation could change the APT after fatigue from a mean of 58.3 (nm) to 91.5 (nm), the AP from 39.4 to 63.6 (nm/s), and the VAS from 90.0 to 12 (mm). But 15 minutes of rest could change the APT from 52.5 to 68.1 (nm), the AP from 37.6 to 48 (nm/s) and the VAS from 90.0 to 27.3 (mm). Conclusion The study showed that soft tissue manipulation was more effective than rest as a strategy to return muscles to a normal state and caused more relief in perceived fatigue.



# Abstract

Background: Muscle fatigue affects the precision of the subjects' performance and limits the range of physical and sports activities. There is limited scientific evidence to support the use of soft tissue manipulation for enhancing muscle performance and its recovery. The aim of the study is comparison of the effects of soft tissue manipulation and rest on the knee extensor muscle fatigue after maximal isokinetic contractions.

Methods: Fifteen healthy females aged 20-30 years selected for research. This study implemented a semi-experimental test-retest measurement method. Each of the volunteers was evaluated three sessions. The first session was to familiarize the volunteers with the test and isokinetics. For the main test, each of the volunteers was evaluated twice with a one-week interval between evaluations. In each session, after warm-up, perceived fatigue using a visual analog scale (VAS), average of peak torque (APT), and average power (AP) for maximal concentric isokinetic output of the quadriceps was measured at a velocity of 60 degrees per second. Then¸ in order to apply the fatigue protocol, the subjects were asked to perform successive maximal quadriceps contractions until three consecutive quadriceps torque outputs reached

below 50 percent maximal torque output. Afterwards, for remeasurement, the average of peak torque and average power were calculated. The extent of perceived fatigue was evaluated as before. Subjects then either rested or received soft tissue manipulation on the knee extensors for a 15-minute duration. After intervention (soft tissue manipulation or rest) parameters were evaluated for third time.

Results: The stability of average peak torque¸ average power, and visual analog scale before performing fatigue protocol was 85%, 83%, and 31.9%, respectively. The stability after fatigue was 43%, 50%, and 93%, respectively. After maximal fatigue and a decrease in torque output to below 50 percent maximal torque, 15 minutes of soft tissue manipulation could change the APT after fatigue from a mean of 58.3 (nm) to 91.5 (nm), the AP from 39.4 to 63.6 (nm/s), and the VAS from 90.0 to 12 (mm). But 15 minutes of rest could change the APT from 52.5 to 68.1 (nm), the AP from 37.6 to 48 (nm/s) and the VAS from 90.0 to 27.3 (mm).

Conclusion: The study showed that soft tissue manipulation was more effective than rest as a strategy to return muscles to a normal state and caused more relief in perceived fatigue.

Key words: Temporal Stability, Muscle fatigue¸ Torque¸ Perceived fatigue, Soft tissue manipulation, Isokinetic

# Background

Muscular fatigue is one of problems which athletes' faces repeatedly while participating in competitive sports or performing therapeutic exercise [1, 2]. When an athlete reaches a certain level beyond his or her physiologic limits, he/she experiences the peril of fatigue. Following muscle fatigue function of metabolic and neuromuscular systems decrease so muscle contraction and continued functioning can't be maintained for a long time [3, 4]. Undoubtedly¸ fatigue affects the precision of the subjects' performance [5]. The manifestation of fatigue not only cause a decrease in the mental and physical performance of the athlete [6], but it also causes sports injuries and physical and mental disorders [7]. Furthermore, fatigue limits the range of physical and sports activities. But there is controversy over whether or not fatigue which occurs during sports or therapeutic exercise is beneficial, and permissible levels of fatigue are always being researched and discussed.

Various approaches to improve muscular performance or slowing down of the signals of muscular fatigue have been studied, including electrotherapy, cryotherapy, heat, and soft tissue manipulation , which is one of the most common methods of fatigue management [8]. In recent years, soft tissue manipulation has found many indications in sports competitions: to assist the athlete in preparing for competition; to assist before back-to-back matches; to promote recovery to a previous state after competition; and to assist when encountering special problems [9].

In spite of the fact that many studies have been shown the effectiveness of soft tissue manipulation , there is still a lot of controversy. For instance, some researchers believe that soft tissue manipulation can

improve some physiologic indexes but doesn't have any effects on muscle performance after fatigue [10-13].

On the contrary, some researches have presented evidence that confirms the positive effects of soft tissue manipulation on muscle performance after fatigue [14-16].

Based on the surveys carried out in 2000-2001, the most common injuries are to the ankle, knee, and leg [17]. Among muscles, the quadriceps is active in almost all physical activities, e.g., running, walking, hitting, etc., also they are influential in decreasing ground reaction force while walking. Hence, its repeated contractions in various activities may cause fatigue.

Due to the aforementioned facts, more awareness about fatigue and way of regain to normal muscle strength for improving performance and prevention of injury is important. In this study we aimed to focus on two enquiries. First, a survey on temporal stability in order to evaluate the parameters of fatigue, including muscle force and individual perceptions of fatigue, which are measured by torque and VAS parameters, respectively. In the next stage, the effects of rest and soft tissue manipulation have been surveyed as two common methods for treating muscle fatigue within torque and VAS parameters.

# Methods

The experimental subject

This study implemented a semi-experimental test-retest measurement method on 15 healthy females aged between 20 and 30, who do some non-professional light sporting activities at least once a week (which mainly include lower limb muscles). Among the subjects, the ones who had already declared their physical fitness and were qualified participated in the trial. Subjects filled forms about background information, such as personal characteristics, and affirmed their health from the point of view of neurology, internal medicine, vascular, orthopedic (especially the injury of dominant knee) with the assistance of examiners. After the physical examination, we ascertained that these subjects didn't suffer from shortened hamstrings in the dominant lower limb, or from genovalgum, genovarum, or genorecurvatum in the dominant knee. None of them has taken medicine affecting the central and peripheral nervous systems and none of them had any dependency or addiction to cigarettes, drugs, or alcohol. The body mass index of these cases was between 18 and 22. During the research, and 24-hours before the first test-session, they didn't do any heavy sporting activity [18]. For this test, only the quadricepses of the dominant limb were tested.

Therapeutic interventions

Either soft tissue manipulation or rest was applied during the first 15-minute recovery period.

Subjects were asked to lie supine and receive soft tissue manipulation for 15 minutes: from groin to superior aspect of the patella, including two minutes of stroking; three minutes of effleurage; petrissage,

i.e., ringing and rolling, each for two minutes; compression for two minutes; and, finally, effleurage for three minutes.

Personal perception of fatigue

The rate of fatigue was evaluated through the use of a visual analog scale (VAS). For this task, the subjects were asked to mark the rate of quadriceps fatigue on a line between zero and one hundred (0-100) [16, 19]. Zero means not having any fatigue and one hundred means the greatest conceivable fatigue. The VAS test in both main sessions was evaluated before and after fatigue and after soft tissue manipulation or rest. Repeatedly, test-takers referred equally to take same trials and this trial was again recorded.

In this research, the VAS was used to evaluate the amount of perceived fatigue. This scale is calculated quickly, and it is convenient and easy for test- takers to understand. Its validity and reliability have also been widely reported for evaluating fatigue [20, 21].

Isokinetic survey of fatigue

In order to warm up at the beginning of each session, resistance-free cycling at an average speed between 60 and 70 revolutions per minutes (rpm) for two minutes' duration was performed.

For measurements of average peak torque and average power of quadriceps, a Biodex System 3 Isokinetic dynamometer was used (Figure 1).

Measurements were taken for a range of motion between 10 to 90 degrees' knee flexion, and back and forth movement, including maximal isokinetic contraction efforts of knee extension (quadriceps), followed by maximal isokinetic contraction efforts of knee flexion (hamstring) in order to let the limb regain its starting state (90 degrees of flexion). At the velocity of 60 degrees per second, three maximal successive concentric isokinetic strength tests of the quadriceps and hamstring were done in order to measure average of peak torque and average power.

Isokinetic tests in both of the main sessions before and after fatigue and after soft tissue manipulation or rest was evaluated. Repeatedly, test-takers referred equally to take trials and this trial was again recorded. During the test, the volunteers were encouraged verbally. Hip-joint position for all individuals was adjusted to 25 degrees of flexion. The average maximal torque from the software of the dynamometer and average power per second were collected with a Newton meter.

Fatigue protocol

Among various methods of evaluating and creating fatigue, voluntary contractions are invariably counted as the first choice, also the application of maximal voluntary contractions is a gold standard for quantifying fatigue [22]. Maximal contractions were implemented to cause fatigue. In cases where

fatigue followed maximal voluntary contraction, we are able to predict the extent and time of occurrence, but if the contractions were submaximal, determining fatigue manifestation was difficult [23].

In this research, we focused on the changes of average peak torque and average power in order to evaluate fatigue. The changes in maximal dynamic torque is one of the best non-invasive methods for measuring muscle injury and recovery *in vivo* [24].

In this research, in order to perform the test, a velocity of 60 degrees per second was applied because applying low velocity is most useful way for a repeatable dynamic fatigue protocol [25].

The choice of a fatigue protocol involving repeated contraction until there is a drop below 50 percent of primary maximal torque output provided accessibility to feedback while executing the fatigue protocol, and this protocol has been shown to be a repeatable and standard criterion [1, 26]. The used fatigue protocol was the maximal isokinetic concentric contraction of knee extension, i.e., for the quadriceps, and submaximal isokinetic concentric contraction of knee flexion, i.e., the hamstring, at a velocity of 60 degrees per second. To perform the fatigue protocol, subjects were asked to perform successive maximal quadriceps contractions until three consecutive quadriceps torque outputs dropped below 50 percent of maximal torque output. Constant monitoring and verbal encouragement by the examiner caused the subjects to try their hardest. “Start” and “stop” was announced by the examiner. After 60 seconds rest, during which the subject remained on the seat, the examiner again announced the “start”, and, as before, successive quadriceps contractions continued until there was another decrease in torque output below 50 percent maximal torque for a $2^{nd}$ and $3^{rd}$ time. There were 60-second rests between each of the three sets.

The stability of test-retest

Reliability means the extent to which the scores of a measuring device are error- free; in other words, in the case of the absence of change in the mentioned concepts in the measuring process, how much the scores of a measurement bear stability [27]. It also means the extent of the temporal correlation among acquired scores from one measuring method during repeated measurements [28].

Each of the volunteers was evaluated in three different sessions. The first session was three days before the main test, in order to familiarize the volunteers with the isokinetic tests. For the main test, each of the volunteers was evaluated twice, with a one-week interval between evaluations. In one of these referrals, subjects received either some soft tissue manipulation after fatigue, or they rested, randomly. Isokinetic and VAS tests in both main sessions before and after fatigue and after soft tissue manipulation or rest were evaluated.

# Results

In order to determine the reliability of the test, an ICC (IntraClass Correlation Coefficient) was implemented to analyze the data gained from the main test. Before fatigue, the stability of average peak torque (APT),

average power (AP), and VAS were consistently 0.85, 0.83, and 0.31, respectively. After the implementation of this protocol, APT was 0.43, AP was 0.50, and VAS was 0.93. Hence, the gained results demonstrate that the stability of APT and AP before fatigue protocol was greater than stability of APT and AP after implementing this protocol. But the effect on perceived fatigue was the other way around, i.e., VAS stability after fatigue was considerably higher than before the fatigue protocol (Table 1, Figure 1).

If the reliability is between 50 and 69, it is average; between 70 and 89 is high; and more than 90 is considered very high reliability [28].

APT, AP, and VAS parameters before fatigue, and between soft tissue manipulation and rest sessions didn't show any significant difference; in the other words, subjects were at the same level of physical fitness and general conditioning. After fatigue, these variables didn't show any significant difference between the two sessions, which shows a similar execution of the fatigue protocol in both the rest and soft tissue manipulation sessions. It was also expected that the fatigue protocol could cause a decrease in torque and power factors and VAS after fatigue was more than before fatigue; this hypothesis has been proven, according to Table 2 and Figure 2. This indicates that inducing fatigue can cause a significant difference torque and power factors in relation to before fatigue protocol. For analysis of data from average peak torque and average power of knee concentric extension and perceived fatigue, which were evaluated at different stages of the soft tissue manipulation and rest sessions and in an inter-session comparison, a paired t-test was applied. The comparison of results showed that in both sessions, parameters such as APT, AP, and VAS after interventions (soft tissue manipulation and rest) had a significant difference ($p = 0.000$) compared to before interventions. This means that both soft tissue manipulation and rest could change these parameters proportionate to proportionate of before applying interventions, e.g., perceived fatigue after fifteen minutes of soft tissue manipulation reduced from 90.06 mm to 12 mm, and after fifteen minutes of rest they decreased from 90.06 mm to 27.3 mm (Table 2). Furthermore, a comparison between these parameters before and after the intervention shows that in any session in which soft tissue manipulation was applied as an intervention, the APT and AP after intervention regressed to the beginning conditions, but for the VAS there was a significant difference between subjects after having soft tissue manipulation as an intervention. On the other hand, in a session which rest was applied, there was a significant difference between APT and VAS after the intervention and at the beginning. In other words, rest couldn´t return these parameters to the preliminary state, but could cause a better recovery in AP (Table 2). Finally, in a comparison between two interventions, i.e., rest and soft tissue manipulation , it was shown that there was a significant difference for the three factors of torque, power, and perceived fatigue between soft tissue manipulation and rest sessions, which means that soft tissue manipulation is more effective than rest for reducing perceived fatigue. Meanwhile, the effect of soft tissue manipulation in regaining strength and power in quadriceps is more than that of rest ($P = 0.000$) (Table 3, Figure 3).

# Discussion

In this research, isokinetic parameters and VAS values were measured three times for each session. Once before applying the fatigue protocol, once after applying the fatigue protocol, and finally, after an intervention. The measurements before fatigue were meant for evaluating the reliability and stability of the VAS and the isokinetic parameters, but the measurements after the fatigue protocol were meant for evaluating the reliability and stability of VAS and the isokinetic parameters after the fatigue protocol.

Furthermore, in this study we had one-week interval between two sessions; in other words, we tried to have a survey on the temporal stability of isokinetic parameters and VAS both before and after the fatigue protocol. The results showed that before fatigue, the temporal stability of the isokinetic device was high, which shows that the recorded torque and power for both of the two repetitions in each session and over time (one week) is a reliable scale. Thus isokinetic dynamometer is appropriate and reliable for evaluating athletes' performance [25]. After fatigue, the stability of torque measurements and isokinetic extensor power was also reliable, but the level of this reliability scored from average to good, and it decreased in comparison with before fatigue. This decrease in stability may be related to the amount of maximal exertion of the individual differs because of local fatigue. In other words, the individual is unable to perceive her maximal muscle power and probably hasn't applied her maximal effort for contraction. The fatigue protocol itself in different sessions (one week apart) may have a different influence in causing fatigue, which can be owing to a difference in the physical, spiritual, and hormonal state of the individual in the two different sessions, or in how much the fatigue protocol is standard or valid regardless of the measurement method. Despite the identical application of the protocol by the test-taker, the amount of fatigue isn't equal. We can deduce from three mentioned assumptions that the isokinetic device or two scales, i.e., torque and power, after fatigue over a long term (one week) is a parameter of less reliability (average to good) for measuring fatigue. For this reason, the stability after fatigue declined. This finding, in comparison with the reliability before fatigue, shows that an isokinetic survey on torque and power itself is reliable, and its decrease is because of individual differences or a weakness in protocol that causes unequal fatigue within a certain time period.

As VAS is a subjective understanding and belief about fatigue, it showed a different result from the isokinetic measurement. Before fatigue, the stability of this scale was low and wasn't even significant. In other words, before performing the fatigue protocol, the individual had no previous experience of the levels of current local fatigue and couldn't have conceived of this fatigue, but the stability of this scale after fatigue was higher than before fatigue, which is probably because the individual had better conception of fatigue after experiencing it. This is why familiarization with evaluating the VAS before applying local fatigue is of greatest significance. Therefore, it can be concluded that VAS is suitable itself for pre-fatigue assessment as a reliable and stable tool, but it is an invaluable and stable criterion to evaluate after fatigue.

As it was mentioned in the results, all tests in both sessions were reliable; in other words, the conditions of individuals and tests were equal in the first and second week, and our fatigue protocol was also able to create an identical sort of fatigue during both sessions. Difference between groups shows that fifteen

minutes of soft tissue manipulation or rest both had a positive effect on recovery, but in the short term, soft tissue manipulation was much more effective than rest.

Mal-Soon and Yun-Hee (2019) performed a survey on twenty-one healthy subjects and stated that soft tissue manipulation can improve muscle strength and proprioception by influencing the superficial layer of the gastrocnemius [2]. In a study by Razeghi and Nouri (2015), 54 healthy athletes performed a fatiguing exercise and subsequently were randomly divided into one of the three groups of cryotherapy, soft tissue manipulation , and control that did not receive any interventions [1]. The schedule of the soft tissue manipulation group consisted of received soft tissue manipulation on the front of the thigh from the groin to the top of the patella for 15 minutes. In this survey, Average Peak Torque (APTQ), Average Power (AP), and Total Work (TW) was measured with an isokinetic dynamometer before and after the test and the results were compared. In the control group, muscle strength showed a significant decline but in the cryotherapy and soft tissue manipulation groups, it increased [1].

Kargarfard et al., (2015) did a study on the effect of soft tissue manipulation on physiological restoration and physical performance on thirty experienced male bodybuilders after exercise protocol. They stated that in comparison with rest, soft tissue manipulation can increase the number of knee extensions and can improve the muscle function [29].

However, Hemings et al. (2000) did a study on eight amateur boxers in two sessions. Boxers first boxed for five two-minute rounds. The researchers reported that soft tissue manipulation had no effect on the repetition of functions in that sport and couldn’t prevent a decrease in force in boxing repetitions. However, soft tissue manipulation could significantly improve the perceived recovery [15]. Also Urio Bender et al., (2019) showed that Soft tissue manipulation therapy slightly decreased pain intensity after habitual running, but had no effect on fatigue [10].

Roberstone et al. (2004) did a survey on 9 healthy male athletes and didn’t find any difference in maximal power and mean power between soft tissue manipulation and passive rest [30].

The present study rejects the conclusion of research carried out by and Roberston et al. (2004) and Bender et al., (2019) in which they mentioned that soft tissue manipulation is not preferable to rest in fatigue recovery and performance [10, 30]. The contradiction between the conclusions of this research and the aforementioned research may stem from a difference in the methodology of the research. The isokinetic dynamometer was not used in any of those studies to make and evaluate fatigue and the method of their evaluation was the repetition of sports activity. Furthermore Bender et al., (2019) suggest that contradiction between the studies about effect of soft tissue manipulation on fatigue is related to level of fatigue [10]. They believe that participants tolerated higher fatigue level in studies that show good effective of soft tissue manipulation therapy compared to Bender et al., study [10].

This research shows that the fatigue protocol can increase the level of perceived fatigue, and after fifteen minutes of soft tissue manipulation or rest, the level of perceived fatigue decreases. The achieved results differed for soft tissue manipulation and rest, and soft tissue manipulation caused less perceived fatigue

than rest. Hence, soft tissue manipulation as a strategy for regaining the original state is more effective than rest and can ameliorate perceived fatigue more, despite the fact that both soft tissue manipulation and rest didn't restore the VAS to its original state, i.e., before the fatigue protocol. In other words, VAS showed a significant difference from the beginning of participation to after the intervention. We can justify that, since each individual's perception of fatigue is different, and the perception of fatigue-levels may not be regained after fifteen minutes of soft tissue manipulation or rest. The VAS value is utterly subjective and, unlike objective parameters, can't return to the original state quickly; i.e., objective parameters may return to their original state after fifteen minutes of soft tissue manipulation but the individual's perception of fatigue may not be completely restored and needs more time to evaluate. On the other hand, the other reason of positive effect of fatigue arises from greater localized blood circulation after soft tissue manipulation therapy that is created either by mechanical effect or temperature increase [14].

Athletes believe that soft tissue manipulation has a positive effect on their activities/ performance and decreases the duration of regaining a normal state after fatigue, which makes better performance in the next competition. Many sport therapists and physiotherapists have also use soft tissue manipulation widely in treating athletes [31]. Analyze of research findings shows a difference between the effects of soft tissue manipulation and rest in relieving fatigue and regaining performance. In other words, soft tissue manipulation could improve performance after maximal fatigue compared to the rest. Thus, soft tissue manipulation is recommended to relieve fatigue and increase movement function during sports and rest intervals.

# Abbreviations

Abbreviations

VAS: visual analog scale

APT: average of peak torque

AP: verage power

# Declarations

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Authors' contributions

Study conception and design: CG and AA. Analysis and interpretation of data, JS and HJ. Drafting of manuscript, MD, AA and HJ. Revision: GG, AA, JS and MD. All authors read and approved the final manuscript.

Ethics approval

The study is approved by ethical committee of Iran University of Medical Sciences. All participants signed a written consent.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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## Tables

Due to technical limitations, tables are only available as a download in the supplemental files section.

## Figures

**Figure 1.** Positioning a subject on Biodex System 3 for doing the trial.

**Figure 1**

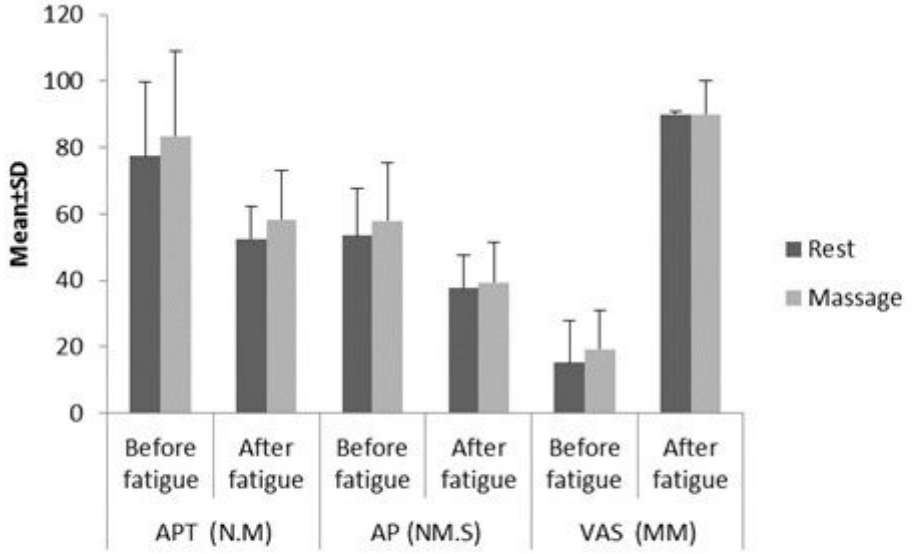


**Figure 1.** Mean, Standard Deviation, and Intraclass Correlation Coefficient (ICC) for torque and perceived fatigue scales

## Figure 2

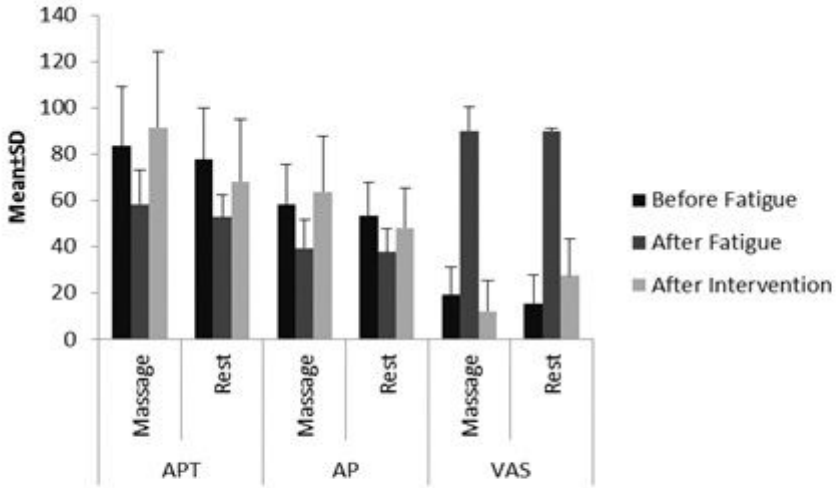


**Figure 2.** The comparison of the APT, AP, and VAS of concentric knee extensors in different stages of evaluation in each session

## Figure 3

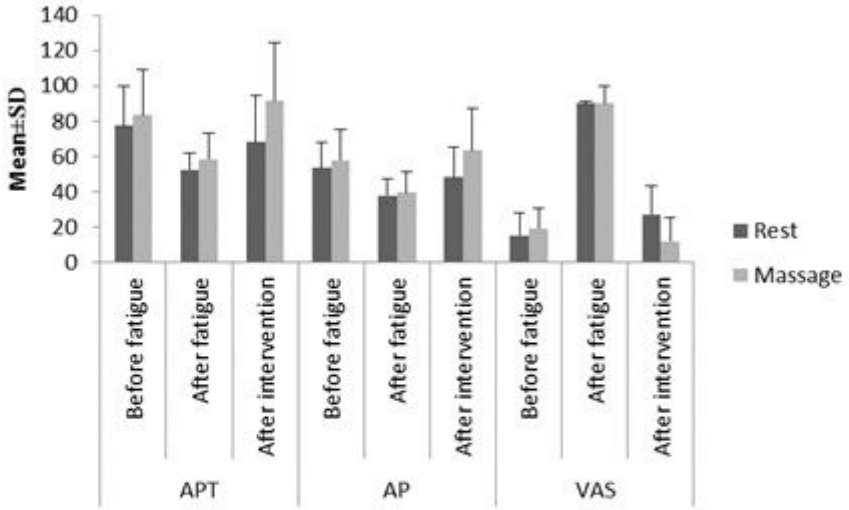


**Figure 3:** The comparison of the APT, AP, and VAS of concentric knee extensors in different stages of evaluation between soft tissue manipulation and rest

Figure 4

# Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.jpg
- Table2.jpg
- Table3.jpg