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ROLE OF FATIGUE ON PROPRIOCEPTION OF THE ANKLE

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ABSTRACT

BURKE GURNEY, JAMES MILANI AND MARYBETH ELIZABETH PEDERSEN. Role of fatigue on proprioception of the ankle. JEPONLINE 3(1):8-13, 2000. Proprioception is comprised of sensory input from several sources including skin, joint capsule/ligaments, and muscle spindles. It remains unclear to what degree each component contributes to the overall proprioceptive picture. If the muscle spindle plays a leading role as currently thought, then muscle fatigue might yield a declination in proprioceptive awareness. The purpose of this study was to examine the role fatigue plays in altering joint repositioning sense in the ankle. Eighty-five (age mean=39.2, ± 12.5, range=19-77 yrs) non-impaired subjects were asked to recognize a pre-determined position of plantarflexion both with and without exercise to fatigue. Order of exercise/non-exercise was randomly assigned. The average of the absolute value deviations from the target position of three trials were recorded as scores for both fatigue and non-fatigue conditions and treated as repeated measures. There was no significant difference in subject's ability to recognize passive repositioning of their ankle with (mean=4.18° ± 1.57°) and without fatigue (m=3.67° ± 1.21°), (F=1.66, p=.20). Muscle fatigue does not seem to play a part in joint repositioning in the ankle. The inconsistency of these results with other findings using similar protocols in the shoulder and knee are discussed.

Key Words: proprioception, fatigue, ankle

INTRODUCTION

Proprioception is defined as the awareness of posture, movement, and changes in equilibrium and the knowledge of position, weight and resistance of objects in relation to the body. It is derived from a complex array of information arriving at the brain from several different sources including the muscle spindle, joint capsule, joint ligaments, skin, fat pads, and possibly the joint cartilage and/or subchondral bone. The individual contributions of the various components of proprioception are not well understood, although historically the joint capsule and ligaments were thought to be the major contributors (1, 2).

If indeed the joint capsule and ligaments are the principle contributors to proprioceptive input, it might be expected that persons with damage to their joint capsules or ligaments might have proprioceptive deficits. Several studies seem to support this supposition (3,4, 5), while others have not (6, 7,).

If the joint capsule and ligament are not the principle contributors to proprioception, then other structures must play a larger role than previously thought. In 1976, the muscle spindle was shown to contribute significantly to position sense in the distal phalangeal joint of the middle finger (8). Studies done in the knee by Skinner et al in 1986 (9) and in the shoulder by Voight et al in 1996 (10) demonstrated that human joints showed significant losses in proprioceptive sense secondary to muscle fatigue. Working under the supposition that the muscle spindle was the only proprioceptive receptor that would be affected by fatigue, the authors concluded that the muscle spindle must play a more important role in joint proprioception than previously thought. However, no research has addressed the role of the muscle spindle in proprioception of the ankle.

The high re-injury rate of the ankle joint was implicitly thought to be a result of damage to the joint capsule and/or ligament including the mechanoreceptors within it. However, it has also been established that damage can occur to the peroneal muscles during repeated injury to the ankle (11). In fact, peroneal muscle weakness has been found to occur in patients with chronic instability of the ankle (12). Therefore, there appears to be a connection between compromised peroneal muscle function and ankle injuries. Therefore, the recurrence of ankle injuries could be due in part to loss of proprioception of the peroneal and other ankle muscles.

If the muscle spindle does play a major role in joint proprioception, and fatigue preferentially affects the muscle spindle as suggested by Voight (10) and Skinner (9), then fatigue may have an effect on the proprioceptive abilities of the ankle as well. Our study was designed to examine the role fatigue plays in altering joint proprioception in the ankle.

METHODS

Study Design

A within-subjects mixed order design was used. Subject's order of participation was randomly assigned to either an experimental (exercise) group first, or a control (non-exercise) group first. The subjects returned no sooner than 48 hours after the first trial to participate in the other half of the study.

Subjects

85 subjects between the ages of 19-77 (mean=39.2, ± 12.5) comprising 28 males and 57 females participated in the study. They completed the consent form approved by the Human Research Review Committee. The subjects had no history of neuromuscular disorders, arthritis, ankle joint sprains or fractures. They were selected by convenience sampling.

Instrumentation

A Cybex II isokinetic dynamometer (Lumex Inc, Ronkonkoma, NY) was used for all exercise and position measurements. Calibration of position and torque was performed on a weekly basis according to manufacturers guidelines.

Procedures

Subjects were measured for height and weight and asked about any pathological conditions that might exclude them from the study. Patient history of ankle (and other) pathology was used as exclusion criteria, no examination was performed on subjects.

Subjects were then positioned on a Cybex isokinetic dynamometer in prone with knee fully extended on the UBXT table with their foot hanging off the edge at approximately mid tibia. Their self-reported dominant foot was then placed in the plantar flexion/dorsiflexion (PF/DF) foot plate lining up the axis of the talo-crural joint with the axis of the Cybex according to manufacturers guidelines.

When participating in the non-exercise session, subjects had their ankles moved passively to a pre-determined target position (20° of PF). Subjects were informed ahead of time that this was the target position and that they were supposed to remember how it felt and that they would be asked to find that same position later. Subjects were kept in the target position until they stated they could remember the position (usually about 5 seconds), passively moved back to neutral (0° PF), and passively taken back into the same target position. This was repeated a total of three times. At no time were subjects allowed to see their foot in the target position. Subjects were then kept on the Cybex in a prone position for exactly ten minutes (approximating the amount of time the exercise session took) with their foot in a comfortable resting position. At the end of the ten minutes, the subject was passively repositioned in the same target position as before (20° PF), and then passively moved back to neutral. The repositioning took about 5 seconds. The subjects were then passively moved at 5°/sec through their range from neutral into plantarflexion by a examiner who was blinded to the digital readout of the Cybex. The subjects were told to inform the examiner to stop when the target position had been reached. The subjects were allowed to ask the examiner to move the ankle position back if they felt the examiner had passed it. A second examiner recorded the digital output of this position. The subjects were then passively moved back to neutral and the procedure was repeated two more times.

The exercise session was identical to the non-exercise session except after the subject was passively placed in the target position three times they completed four sets of 43 repetitions of plantar/dorsiflexion isokinetic concentric exercises at 90°/second. This number of sets/reps was chosen because it consistently created a 50% peak torque declination of both dorsiflexors and plantar flexors in pilot studies. Torque output was recorded throughout the exercise. The subjects were given thirty seconds between sets to recover from any discomfort. At the end of the fourth set, subjects were again given thirty seconds to allow any discomfort such as muscle burning to subside. Thirty seconds was chosen because that was consistent with the amount of time necessary to allow muscle burning to subside that might have otherwise interfered with joint repositioning sense in addition to that of muscle fatigue. They were then passively placed in the target position once again so they reached the position within the 30 second recovery period, passively moved back to neutral, and passively moved through plantarflexion identical to the non-exercise session. All scores were recorded as subject reported positions in degrees. The subject's score comprised the average of the three absolute value differences between their reported positions and 20° of PF. This score was calculated for both the exercise and non-exercise sessions.

Statistics

Statistical analyses were completed using ANOVA with repeated measures (SPSS 6.1, Chicago, II). Results of testing revealed that the testing method was reliable. An intraclass correlation coefficient was calculated and was found to be acceptable (ICC = 0.93).

The dependent variable (DV) was calculated by taking the absolute value differences in degrees from the target position of the three repetitions. These values were averaged for both levels of the independent variable (exercise and non-exercise) and treated as repeated measures. Bivariate correlations were completed between percent fatigue of the plantar flexors and position error as well as percent fatigue of the dorsiflexors and position error. Order was also examined to ensure that order of exercise to non-exercise was not a factor.

RESULTS

All subjects fatigued to the point that their peak torque output decreased by at least 50% in the dorsiflexors (mean=62.5% ± 12.2), and 26 of the 85 experienced at least 50% fatigue in the plantarflexors (mean=41.5% ±23.4).

There was no significant difference between groups of individuals based on the order of treatment that they received. The group that received exercise first had similar mean score values (mean=3.94°±1.36° with exercise, mean=3.83°±1.32° without exercise) compared to the group that received non-exercise first (mean=4.61°±1.76° with exercise, mean=3.60°±1.16° without exercise), (F=.21, p=0.65).

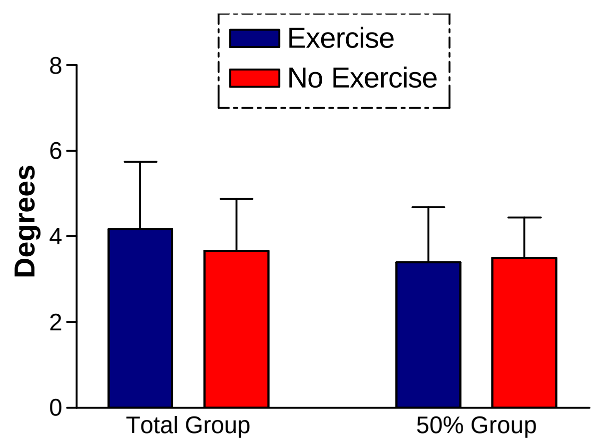

Figure 1: Difference in degrees between target position and subject-selected position with and without exercise in both the entire subject population (n=85) (left), and those subjects who displayed at least a 50% peak torque fatigue in both dorsiflexors and plantarflexors (n=26) (right).

No significant difference was found in the means of absolute value scores between the exercise to fatigue (mean=4.18° ±1.57°) verses the non-exercise bouts (mean=3.67° ± 1.21°), (F=1.66, p=0.20) (Figure 1, left). When only subjects who achieved a minimum of 50% peak torque fatigue of the plantarflexors were considered (N=26), the mean difference between exercise (mean=3.4° ± 1.28°) and non-exercise (mean=3.5° ± 0.95°) became even less, (F=0.03, p=.86) (Figure 1, right). The correlation between % fatigue of plantar flexion and position error was -0.2643 (p=0.19) and the correlation between % fatigue of dorsiflexion and position error was –0.0980 (p=0.494). Using p = 0.5, a power analysis of the results yielded a statistical power of 74.2% (mean=4.18° ± 1.57°, mean=3.67° ± 1.21°).

DISCUSSION

The findings of no effect of fatigue on proprioception in this study are inconsistent with similar protocols used by Skinner in the knee (9) and Voight in the shoulder (10). There are several possible explanations of these inconsistencies.

First, the protocols of both the knee and shoulder studies differed from our protocol. While the Skinner (9) study looked only at passive repositioning of the knee, the Voight study (10) looked at both active and passive repositioning of the shoulder. It is unclear from the publications whether the authors combined the active and passive repositioning scores when calculating significance. In our protocol, we deliberately excluded active repositioning because we felt that extreme fatigue could hinder the subject’s ability to reposition the foot accurately even when the proprioceptive system was intact, possibly due to severe α-motor neuron fatigue.

Secondly, although it seems reasonable to assume that absolute values were used in calculating repositioning scores in the two studies, it is not clearly stated. If simple average scores were used, then a person who repositioned 10° above 110° followed by two trials 5° below 110°, as an example, would end up with an average of exactly 110° and would appear “better” than a person who had three trials within 2°. Interestingly, when we calculated our findings using values that were not absolute, we achieved significance. However, we felt that this was not clinically meaningful.

There are several possible explanations as to why there was no significant difference between fatigue and non-fatigue scores in this study. First of all, there was a moderate level of statistical power for this study. In addition, there was a great deal of variance in the subjects' ability to position their ankle joints at a similar angle between the two trials (but independent of fatigue). This large amount of variance could have overshadowed the small amount of difference associated with fatigue. This could be interpreted to mean that there were insufficient levels of fatigue to show a difference between the exercise and non-exercise trials. However, if this were the case, one would expect that there would have been a larger difference in the sub-population of persons who showed more of a peak torque declination. The opposite was the case. Persons showing a 50% or greater peak torque declination had a smaller difference in joint repositioning sense with and without exercise. For whatever reason, however, there appears to be a trivial association between fatigue and joint repositioning sense in our study.

Another possible explanation for our findings is that the muscle spindle in the ankle does not fatigue along with its motor counterpart. If this is the case, even in the event of significant α-motor neuron fatigue, the γ-afferent system may remain intact. The significant findings of Voight (10) and Skinner (9) might have been due to a confounding variable such as counter-stimulus from muscle fatigue pain or simple sensory overload. It may also be that the ankle might have a fatigue resistant γ-afferent system to insure safety in long term righting responses. That would explain why subjects had intact muscle spindle proprioceptive input even in the presence of muscle fatigue.

Still another explanation is the possibility that even though the dorsiflexors and plantar flexors showed significant fatigue (50% or greater peak torque declination in DF for all subjects, and 50% or greater peak torque declination in 26 subjects), muscle groups such as the evertors did not fatigue as completely, and were able to relay enough proprioceptive information to compensate for the fatigued muscles. This seems unlikely, however, since the evertors are active in plantarflexion and would therefore fatigue with repeated bouts of maximal exercise in plantarflexion such as with our protocol.

Finally, a possibility exists that the ankle differs from the knee and shoulder in that the ankle is more dependent on ligamentous and capsular (and other) components of proprioception. The studies by Lentell (4), Garn (3) and Bullock-Saxton (5) showed that individuals with chronic ankle injuries had demonstrable deficits in several indices of proprioceptive measure. In addition, the study by Konradsen et al (7) showed that passive position sense was impaired with an anaesthetized ankle joint. The fact that Konradsen found no differences in one-legged stance sway could be explained by the contribution of the vestibular system and optic system (as his single-leg stance measures were done with eyes open) compensating for the loss of the ligamentous/capsular input.

There were several methodological concerns that might have compromised external validity. First of, exercise to fatigue was performed open chain. In normal functional activities, ankle fatigue usually occurs in closed chain exercise. The authors reasoned that it would have been extremely difficult to objectively and consistently fatigue the ankle joint in a closed chain manner. In addition, the authors could find no way to measure the degree of fatigue or the torque output during the closed chain exercise. The Cybex offered a consistent, reproducible way to fatigue the ankle that was easily measurable.

Secondly, an argument could be made that ankle inversion/eversion exercise would have been more representative of the mechanism of ankle sprain injury. The authors reasoned, however, that plantarflexion is a component of the mechanism of injury in ankle sprain and would therefore address this issue. In addition, they reasoned that testing a joint that moves predominantly on a single axis would yield more reproducible data than the tri-planer movement of inversion/eversion. Pilot studies proved this to be correct. Intraclass correlation coefficients with ankle were consistently lower with ankle inversion/eversion (ICC = 0.77) when compared to ankle DF/PF (ICC = 0.93).

Finally, the subjects were all devoid of ankle injury. The authors reasoned that using subjects with injured ankles would have introduced a variable that would have been difficult to control in both identification of the injured tissue and quantify the degree of ankle injury.

CONCLUSIONS

The details of proprioception are still largely unknown. It is known that proprioception is necessary for normal functional activities and loss of proprioception greatly impedes coordination and predisposes one

to injury and re-injury. The muscle spindle may provide a main component of joint proprioception, but it appears from the results of this study that non-weight bearing proprioception of the ankle joint is not altered by muscular fatigue of the plantar and dorsi-flexors.

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