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# Military Exercises, Knee and Ankle Joint Position Sense, and Injury in Male Conscripts: A Pilot Study

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***Context:*** The high incidence of lower limb injuries associated with physical exercises in military conscripts suggests that fatigue may be a risk factor for injuries. Researchers have hypothesized that lower limb injuries may be related to altered ankle and knee joint position sense (JPS) due to fatigue.

***Objective:*** To evaluate if military exercises could alter JPS and to examine the possible relation of JPS to future lower extremity injuries in military service.

***Design:*** Cohort study.

***Setting:*** Laboratory.

***Patients or Other Participants:*** A total of 50 male conscripts (age = 21.4 ± 2.3 years, height = 174.5 ± 6.4 cm, mass = 73.1 ± 6.3 kg) from a unique military base were recruited randomly.

***Main Outcome Measure(s):*** Participants performed 8 weeks of physical activities at the beginning of a military course. In the first part of the study, we instructed participants to recognize predetermined positions before and after military exercises so we could examine the effects of military exercise on JPS. The averages of the absolute error and the variable error of 3 trials were recorded. We collected data on the frequency of lower extremity injuries over 8 weeks. Next, the participants were divided into 2 groups: injured and uninjured. Separate 2 × 2 × 2 (group-by-time-by-joint) mixed-model analyses of variance were used to determine main effects and interactions of these factors for each JPS measure. In the second part of the study, we examined whether the effects of fatigue on JPS were related to the development of injury during an 8-week training program. We calculated Hedges effect sizes for JPS changes postexercise in each group and compared change scores between groups.

***Results:*** We found group-by-time interactions for all JPS variables ($F$ range = 2.86–4.05, $P < .01$). All participants showed increases in JPS errors postexercise ($P < .01$), but the injured group had greater changes for all the variables ($P < .01$).

***Conclusions:*** Military conscripts who sustained lower extremity injuries during an 8-week military exercise program had greater loss of JPS acuity than conscripts who did not sustain injuries. The changes in JPS found after 1 bout of exercise may have predictive ability for future musculoskeletal injuries.

***Key Words:*** fatigue, proprioception, lower extremity, muscles

**Key Points**

- After an 8-week military exercise program, the loss of joint position sense (JPS) acuity was greater in injured than in uninjured conscripts.
- The JPS changes were greater in the ankle than in the knee joint.
- Greater JPS changes postexercise might increase the risk of subsequent musculoskeletal injury during basic training.

Army recruits engage in a rigorous exercise training program during their initial months of military conscription to achieve a high level of physical fitness. Given the strenuous physical effort involved in military personnel activities, musculoskeletal injuries are a major problem in military populations. Injuries are important in terms of treatment costs, loss of time from work, and decreased military readiness. Most of these injuries are lower extremity injuries that usually occur at or below the knee.[1,2]

Jones et al[3] reported that the 5 most commonly diagnosed conditions in military populations were pain attributed to overuse or stress syndrome (23.8%), muscle strains (8.6%), ankle sprains (6.3%), overuse knee injuries (5.9%), and stress fractures (3.0%). The leading causes of injuries resulting in hospitalizations were falls and accidents in land transport.[2] The literature clearly has shown that the rates of injury associated with vigorous weight-bearing exercise, such as marching or jumping, are high, and as the frequency, duration, or total amount of training increases, the injuries also increase.[1]

Although acute trauma may be a factor in some cases, many musculoskeletal injuries result from the cumulative effects of microtraumatic forces that occur with overtraining, repetitive movements and activities, forceful actions, extreme joint positions, and prolonged static positioning.[4] Based on the literature, fatigue due to repetitive strenuous physical activities may be a factor in musculoskeletal injuries, especially in military participants and athletes.[1,4]

Proprioception is derived from several different sources, including articular mechanoreceptors; cutaneous afferents; and muscle, visual, and vestibular receptors.[5] Joint position sense (JPS) as a functional measure of proprioception plays an important role in maintaining the functional (dynamic) stability of joints, especially in the lower extremity.[5,6] Researchers have hypothesized that proprioceptive deficits might be a risk factor for lower extremity injury. Participants with functional instability are more likely to sustain an ankle injury than healthy participants.[7] Moreover, investigators have shown that proprioceptive deficit at the ankle joint is a predictor of ankle injury[8] and less accurate JPS is an important risk factor for ankle sprain in young, physically active females.[9] In addition, JPS deficits due to fatigue may be associated with lower extremity musculoskeletal injuries.[10] The incidence of injury to skiers and football players was higher in the afternoon and in the third quarter, respectively,[10,11] suggesting that fatigue may produce a decline in proprioception and may be a risk factor for lower extremity injuries.[5,10,11]

Moreover, one of the most notable findings in participants with lower extremity musculoskeletal injuries is a deficit in knee or ankle JPS.[12,13] However, determining if this deficit was present before and potentially contributed to the injuries or if it resulted from the injuries is difficult. Emerging epidemiologic evidence suggests that exercise-induced fatigue may lead to deficits in JPS, which in turn may lead to an increased risk of lower extremity injury during exercise and military training. Studies are needed to directly assess the effects of fatigue on ankle and knee neuromuscular functions, especially JPS after military exercises, and its possible effect on making the joint susceptible to injury. Therefore, the purpose of our study was to determine if military exercise was associated with a reduction in JPS accuracy in the knee and ankle joints. A secondary objective was to determine if a relationship existed between JPS and lower extremity injury during an 8-week follow-up period.

## METHODS

### Design

Our prospective cohort study had 2 objectives: (1) to examine the immediate effects of military exercise on ankle and knee JPS and (2) to determine the relationship between JPS and lower extremity injury during an 8-week follow-up period.

### Participants

For our prospective cohort study, we randomly selected 50 male conscripts from an original population of 320 conscripts from a unique military base (age = 21.4 ± 2.3 years, height = 174.5 ± 6.4 cm, mass = 73.1 ± 6.3 kg) at the same time point in their basic combat training. A physician (not an author) checked their health status and any medical history and documents during the first day of service. If a conscript had the onset of any severe disease or injury before the beginning of the service, he was discharged. Based on medical documents, no participant had a history of ankle or knee joint trauma or surgery. A physiotherapist (author F. M.) evaluated all participants. Using a goniometer (Benchmark Medical, Inc, Malvern, PA), he did not find restricted knee or ankle joint mobility in any participant. Next, the conscripts were tested for JPS at the beginning of their military training. All participants provided informed consent, and the study was approved by the AJA University of Medical Sciences Committee for Health Sciences Research Involving Human Subjects.

### Physical Training Program

In the beginning of military service, all conscripts perform 8 weeks of physical activities, including marching, orienteering, drill training, and combat training. The average military training is 25 hours per week, and the duration and difficulty of training are designed to increase gradually. In addition, conscripts perform physical exercises, such as jogging (10 minutes); timed and distance running (20 minutes); circuit training (10 minutes); weight exercises (20 minutes); push-ups, sit-ups, and pull-ups (20 minutes); and team sports (30 minutes), with 10 minutes of rest for 2 hours per day. The duration of exercises is held constant for all participants.

### Musculoskeletal Injury Diagnosis

We followed all participants for 8 weeks and recorded data on the frequency of any musculoskeletal disorders. A *musculoskeletal disorder*, including overuse and acute injuries, was defined as an event that resulted in physical damage to the body and for which the conscript sought medical care from the clinic.[14] Participants with overuse injuries primarily due to physical training and acute injuries that had occurred during physical training were selected for the study. At the clinic, a physician (not an author) completed a questionnaire describing the type, anatomic location, severity, and cause of the disorder.

### Measurement of JPS

We randomly tested all participants to assess their JPS of the ankle and knee on 2 consecutive days 2.6 ± 1.4 minutes before and 1.8 ± 1.1 minutes after military exercises; given that the study was not conducted in the field, it took some time for the participants to move from the field to the laboratory. We used the Biodex 2 isokinetic dynamometer (Biodex Medical Systems, Inc, Shirley, NY), which has been reported as a valid instrument to measure JPS.[15] Only the *dominant limb*, which was defined as the limb used to kick a soccer ball, was tested. Participants wore blindfolds to ensure elimination of visual cues and used ear plugs to eliminate auditory cues. Before starting the experimental trials, they performed 3 practice trials. Measurement of JPS was repeated 3 times, and average scores were used for analysis.

### Positioning of Participants and Target Angles

For ankle joint testing, each participant lay supine on the associated chair with the calf of the test leg resting on a 40-cm-high platform. The bare foot of the participant was aligned with the axis of the dynamometer and attached to the footplate by a small wrap to reduce cutaneous receptor input. The talocrural joint was in 15° of plantar flexion (Figure 1). The target position was 15° of inversion.[15]

For knee joint testing, each participant sat on the testing seat with the hip flexed to 90°. The tibial pad was secured to the shank of the leg 3 cm superior to the lateral malleolus (Figure 2). The target position was 45° of flexion, which is


**Figure 1. Joint position sense measurement of the ankle joint.**

in the working range of the knee during daily weight-bearing activities.[16]

## Passive and Active Testing Procedure

For passive testing, the participant's foot and knee were moved from the neutral position and 90° of flexion, respectively, to the predetermined test position and held there for 10 seconds. Each participant was instructed to concentrate on the position of the foot. The foot or knee then was returned passively to the starting position with a speed of 5°/s using the protocol described by Taanila et al[14] and Gurney et al.[17] This cycle was performed again, and the participant was instructed to push a button to stop when he thought the test position had been reached. The active test was performed in the same manner except after having the foot or knee passively placed in the test position and moved back to the starting position, the participant was instructed to actively move the foot or knee to reproduce the same test position. The participant again was instructed to push a button to stop when he thought the test position was reached.

## Data Reduction

We used 4 dependent variables for each joint to assess JPS matching performances: active and passive absolute error (AE), which is the difference in absolute value in degrees between the position chosen by the participant and the test position angle, and active and passive variable error (VE), which is the variance around the mean value. The AE and VE are measures of the overall accuracy and the variability of the positioning, respectively. Decreased AE and VE scores indicate increased accuracy and consistency of the positioning, respectively.[18]

## Statistical Analysis

We used SPSS (version 16.0 for Windows; IBM Corporation, Chicago, IL) and Excel 2007 (Microsoft Corporation, Redmond, WA) for statistical analysis.

**Effect of Fatigue on Ankle and Knee JPS.** At the end of 8 weeks, the participants were divided into 2 groups: injured and uninjured (Table 1). To examine the main effects and interactions of JPS variables, we used separate 2 $\times$ 2 $\times$ 2 (group-by-time-by-joint) mixed-model analyses of variance. We used Tukey post hoc testing to identify which pairwise comparisons were different from one another. For all analyses, the $\alpha$ level was set at equal to or less than .05.

**JPS Changes and Injury.** To assess whether changes in JPS were related prospectively to injury during the 8-week military training program and given that the sample size of the injured group was too small to run a regression analysis,


Figure 2. Joint position sense measurement of the knee joint.

we computed the standardized mean-difference effect size (ES) corrected for small-sample bias (Hedges g) for JPS values from pre-exercise to postexercise for each group and corresponding change scores between groups. Effect sizes equal to or less than 0.2 are thought to be small; around 0.5, medium; and greater than 0.8, large.[19]

## RESULTS

### Rate of Injury

During the 8-week follow-up, a total of 9 injuries (18% of participants) were diagnosed, and 8 (16%) affected the lower extremity. We found 3 hamstrings strains, 3 ankle sprains, 1 anterior cruciate ligament (ACL) rupture, 1 low back pain, and 1 metatarsal stress fracture. Only lower extremity injuries were analyzed. Participant characteristics in the injured and uninjured groups are presented in Table 1. Groups were similar in age, height, mass, and body mass index.

**Table 1. Participants' Characteristics (Mean ± SD)**

| | Participants | |
|---|---|---|
| Characteristic | Injured (n = 8) | Uninjured (n = 42) |
| Age, y | 21.9 ± 0.5 | 21.5 ± 1.9 |
| Height, cm | 175.1 ± 3.9 | 174.9 ± 5.8 |
| Mass, kg | 72.9 ± 4.6 | 74.1 ± 5.6 |
| Body mass index, kg/m$^2$ | 23.7 ± 2.4 | 23.9 ± 4.7 |

### Effect of Fatigue on JPS

We did not find group-by-time-by-joint, group-by-joint, or time-by-joint interactions for any of the dependent variables, but we noted an interaction effect between group and time across all JPS variables ($F$ range = 2.86–4.05, $P <$ .01) (Figure 3). Post hoc analysis revealed that both the injured and uninjured groups had increases in JPS errors postexercise ($P <$ .01), but the changes in the injured group were greater than in the uninjured group for all variables ($P <$ .01).

### JPS Changes and Injury

Mean pre- and postexercise JPS values, bias-corrected ESs for each value, and confidence intervals are shown in Table 2. The positive Hedges g measures revealed that the JPS errors were greater after fatiguing exercise in injured than uninjured conscripts. Moreover, fatigue had a greater effect on ankle than on knee measures. The active values showed the same pattern as passive values. Mean differences between the change scores of the groups, bias-corrected ESs, and the confidence intervals are shown in Table 3. All values showed positive ESs; the fatigue effect was greater in the injured group. Furthermore, with the exception of knee VE values, the magnitudes of all ESs in JPS changes after fatiguing exercise were greater than 0.80, indicating that the fatigue effect was notably higher in the injured than in the uninjured group. The most sensitive JPS variable was ankle active AE, which showed an ES of 3.31 for the difference between the 2 groups.

## DISCUSSION

We demonstrated that the acuity of JPS was reduced after military exercises, which supports the view that fatigue may influence the receptors around the ankle and knee joints.[20,21] The JPS is derived from several different sources, including articular mechanoreceptors, cutaneous afferents, and muscle receptors.[17] The neural input provided by mechanoreceptors and the visual and vestibular receptors are integrated by the central nervous system to generate motor response.[15] Increased joint laxity,[22] decreased muscle receptor activity,[23] and nociceptors that are activated by metabolic products of muscle contraction and inflammatory substances[24] are possible mechanisms by which fatigue may influence JPS. Given that no one has investigated the effects of military exercises on ankle and knee JPS, our results may be comparable with the results of investigations in the sport field. The same pattern of findings (increase in JPS errors) was obtained in other studies of the ankle[24–26] and knee joints.[5,23,27,28] In most of these studies, the authors applied local fatigue in the laboratory to produce local fatigue, which may cause dysfunction of muscle mechanoreceptors.[5] We applied a

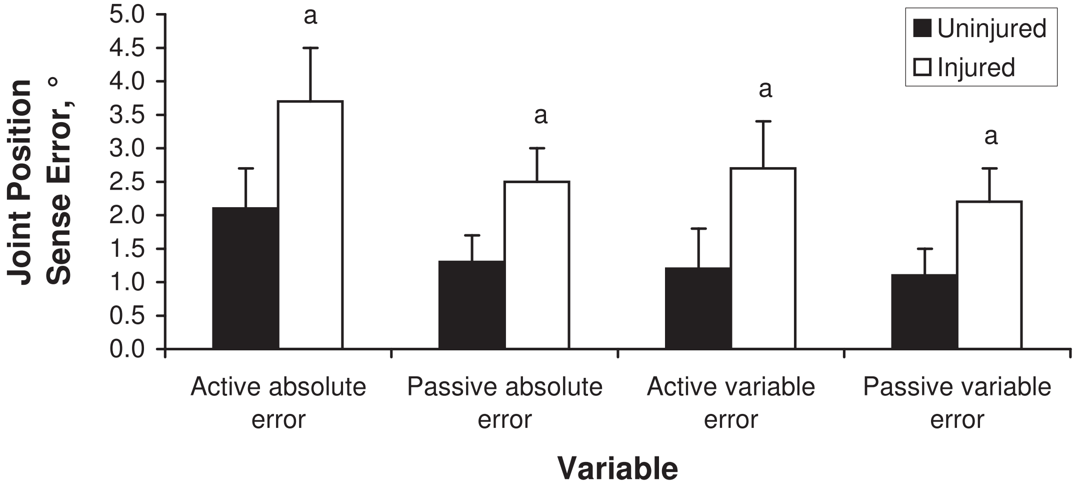


**Figure 3. The group-by-time interactions of joint position sense variables. [a] Indicates post hoc difference between uninjured and injured groups ($P < .01$).**

general load that may produce not only local fatigue of the ankle and knee joints but also general fatigue that affects other mechanisms in the proprioception pathway.

Whereas the change in JPS appeared to be systemic (the JPS errors of both ankle and knee joints were increased postexercise), the ankle joint seemed to be affected more than the knee. Based on the ESs, the changes in the ankle variables were twice as large as their corresponding knee variables. This finding could raise the possibility that the distal joints are more susceptible to fatigue effects. To our knowledge, no one has compared the effect of fatigue on these 2 joints. Further studies should be undertaken to investigate these findings. Bellew and Fenter[29] demonstrated that static postural control was impaired after ankle musculature fatigue but not after knee musculature fatigue. Evaluating the postural control is an alternative method to determine the combination of peripheral, vestibular, and visual contributions to neuromuscular control, so the results of their study might be comparable with ours. In a similar study, Gribble and Hertel[30] hypothesized that fatigue induced by segmental movements strongly affects distal postural muscles. This finding may emphasize the importance of making appropriate postural adjustments to prevent lower extremity injuries. Further studies are needed to examine this supposition.

The results indicated more accurate JPS values in active than passive repositioning. Kalaska[31] suggested that the proprioceptive system may be better tuned to active muscular movements than to movements imposed passively by external forces. This finding is also consistent with the results of Laufer et al,[32] who found that decreased accuracy and greater directional biases when encoding the target location were achieved by passive rather than active movements. Moreover, whereas both active and passive values were affected by military exercise, the increase in JPS errors postexercise was higher for active than for passive values. Given that muscle receptors are subject to central control,[17,21] input from these peripheral receptors might be more altered by fatigue when the participant is

**Table 2. Joint Position Sense Measures for Injured and Uninjured Participants**

| Joint | Outcome Measure | Group | Mean ± SD | | Bias Correction (Hedges g) | 95% Confidence Interval for Effect Size |
|---|---|---|---|---|---|---|
| | | | Pre-Exercise | Postexercise | | |
| Ankle | Active absolute error[a] | Injured | 1.6 ± 0.4 | 3.4 ± 0.9 | 2.44 | 1.15, 3.74 |
| | | Uninjured | 1.6 ± 0.3 | 2.2 ± 0.4 | 1.68 | 1.18, 2.18 |
| | Passive absolute error | Injured | 2.5 ± 0.6 | 4.5 ± 1.2 | 1.99 | 0.79, 3.19 |
| | | Uninjured | 2.4 ± 0.5 | 3.1 ± 0.8 | 1.04 | 0.58, 1.50 |
| | Active variable error[b] | Injured | 0.9 ± 0.3 | 2.3 ± 0.6 | 2.79 | 1.41, 3.17 |
| | | Uninjured | 0.8 ± 0.2 | 1.2 ± 0.3 | 1.55 | 1.07, 2.04 |
| | Passive variable error | Injured | 1.7 ± 0.5 | 3.2 ± 0.8 | 2.13 | 0.90, 3.05 |
| | | Uninjured | 1.5 ± 0.4 | 2.1 ± 0.5 | 1.31 | 0.84, 1.78 |
| Knee | Active absolute error | Injured | 2.8 ± 0.7 | 4.3 ± 0.9 | 2.49 | 1.59, 3.09 |
| | | Uninjured | 2.6 ± 0.6 | 3.1 ± 0.7 | 1.58 | 0.99, 2.16 |
| | Passive absolute error | Injured | 2.9 ± 0.7 | 4.7 ± 0.9 | 2.35 | 1.10, 2.91 |
| | | Uninjured | 2.8 ± 0.6 | 3.3 ± 0.8 | 1.22 | 0.68, 1.76 |
| | Active variable error | Injured | 1.7 ± 0.5 | 2.7 ± 0.6 | 0.79 | 0.38, 1.40 |
| | | Uninjured | 1.6 ± 0.4 | 2.0 ± 0.5 | 0.69 | 0.19, 1.18 |
| | Passive variable error | Injured | 2.2 ± 0.5 | 3.5 ± 0.7 | 0.20 | 0.07, 0.38 |
| | | Uninjured | 2.0 ± 0.4 | 2.5 ± 0.6 | 0.08 | 0.05, 0.11 |

[a] *Absolute error* is the difference in absolute value (°) between the position chosen by the participant and the test position angle.
[b] *Variable error* is the variance around the mean value.

Table 3. Joint Position Sense Measures for Injured and Uninjured Participants After Fatiguing Exercise

| Joint | Outcome Measure | Mean ± SD: Injured Group | Mean ± SD: Uninjured Group | Bias Correction (Hedges g) | 95% Confidence Interval for Effect Size |
|---|---|---|---|---|---|
| Ankle | Active absolute error[a] | 1.8 ± 0.8 | 0.7 ± 0.3 | 3.31 | 2.31, 4.30 |
| | Passive absolute error | 1.7 ± 0.5 | 0.6 ± 0.2 | 2.92 | 1.98, 3.87 |
| | Active variable error[b] | 1.5 ± 0.5 | 0.7 ± 0.3 | 2.76 | 1.83, 3.69 |
| | Passive variable error | 1.0 ± 0.4 | 0.5 ± 0.1 | 1.76 | 1.14, 2.37 |
| Knee | Active absolute error | 1.6 ± 0.5 | 0.7 ± 0.3 | 1.47 | 0.90, 2.04 |
| | Passive absolute error | 1.5 ± 0.4 | 0.6 ± 0.2 | 1.06 | 0.54, 1.59 |
| | Active variable error | 1.2 ± 0.4 | 0.5 ± 0.2 | 0.46 | 0.23, 0.94 |
| | Passive variable error | 1.0 ± 0.4 | 0.5 ± 0.2 | 0.40 | 0.17, 0.77 |

[a] *Absolute error* is the difference in absolute value (°) between the position chosen by the participant and the test position angle.
[b] *Variable error* is the variance around the mean value.

instructed to actively move the joint to reproduce the target position.

During the follow-up, 8 lower extremity injuries (3 hamstrings strains, 3 ankle sprains, 1 ACL rupture, and 1 metatarsal stress fracture) were diagnosed; these represent the 5 most commonly diagnosed conditions in military populations (overuse or stress syndrome, muscle strains, ankle sprains, knee injuries, and stress fractures).[3] Although acute traumatic and overuse injuries have different mechanisms, we analyzed both. Justifications for this decision include the detrimental effect of overuse injuries on the large treatment costs, loss of time from work, and effectiveness of a military training program.[33]

Both injured and uninjured participants showed an increase in JPS errors after a fatigue condition. The most striking result to emerge from the data was that JPS after a single bout of exercise deteriorated more in conscripts who developed musculoskeletal injuries than in uninjured conscripts, which means that the effect of fatigue was greater for the former. To our knowledge, no one has evaluated the effects of fatigue on JPS in participants with and without musculoskeletal injury. However, decreased JPS acuity has been reported in participants with musculoskeletal injuries. Roberts et al[34] found that poorer proprioception was related to lateral cartilage lesions and increased laxity in ACL-deficient knees, also suggesting a relation between proprioception and subjective knee function. Parkhurst and Burnett[35] reported that low back injuries were correlated with proprioceptive deficits in the coronal, sagittal, and multiple planes. They showed that proprioceptive asymmetries were associated with low back injuries. The increased effect of fatigue on JPS could be a cause of increased injury rates in the conscripts. Given the small sample size of the injured group, we could not run a regression analysis to examine whether these conscripts were susceptible to musculoskeletal injury. However, based on the different ESs of JPS changes in the injured group, we assume that increased JPS error after training could predict further musculoskeletal injury and will increase the risk of conscripts being classified as injured. This finding is consistent with the results of other studies[5,7–11] suggesting that JPS deficits due to fatigue may be a risk factor for lower extremity musculoskeletal injuries. In agreement with our results, Wilson and Madigan[36] suggested that proprioceptive deficits due to injury could make the joint susceptible to reinjury. One could hypothesize that the ability to detect position sense of the lower extremity and to make postural adjustments in response is crucial for preventing lower extremity injuries.[15] Based on the results of the Hedges g analysis, ankle active AE showed the largest differences in the JPS changes between the 2 groups. Thus, evaluating the effect of fatigue on this JPS variable may provide a useful method for assessing conscripts to distinguish who might be susceptible to injury. The data obtained from this study may be useful in future studies and may be useful when conducting clinical examinations for predicting the incidence of injury.

Our study had some limitations. First, the sample comprised exclusively young, male participants to avoid possible differences caused by sex, and participants with acute traumatic injuries and participants with overuse injuries were both categorized as the injured group. In addition, the JPS of 2 joints was measured in 1 target position for each joint. Moreover, the results were obtained after 1 bout of military exercise training, and we are not certain if other exercises would elicit similar effects. Larger-scale prospective studies in which a greater number of conscripts are followed over time are warranted to potentially identify more injuries over a longer period and quantitatively explore the predictive ability of these measures.

## CONCLUSIONS

After military exercises, the JPS errors of ankle and knee joints were increased, but the loss of JPS was greater in injured conscripts. The JPS changes were greater in the ankle joint, suggesting that these changes postexercise might increase the risk of subsequently sustaining an injury during basic training.

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