Introduction

Over 100 years ago Goldscheider [29] systematically measured and compared the smallest joint rotations that could be detected at nine different joints in the body. As a result of 4,000 measurements made at a constant velocity (0.3°/s) he reported that the ankle exhibited the highest threshold (1.2°) and the shoulder the lowest threshold (0.2°) of the joints studied. Goldscheider was one of the first to systematically quantify the awareness of body segment positions and orientations, later defined as “proprioception” by Sherrington [62], who coined the term from the Latin *receptus* (the act of receiving) and *propius* (one’s own). The classic methods for testing proprioception involve (a) using methods similar to those of Goldscheider to determine the *lowest threshold for detecting joint rotation* and (b) determining *joint position sense* from the accuracy with which contralateral joint angles can be matched or a limb segment repositioned in three-dimensional space.
Without the aid of vision. The threshold for detecting joint rotation is one critical factor in preventing joint injury. Modern methods for testing such thresholds (for review see [3, 55]) employ known joint rotation velocities because of the velocity-dependent nature of the threshold (lower thresholds are found at higher velocities), the desired probability of sensing a given threshold, as well as weight-bearing and non-weight-bearing test conditions. For example, correctly detecting ankle inversion with a 75% probability of success requires a mean threshold rotation of 0.09±0.09° in healthy young adults and 0.39±0.44° in healthy 70-year-old subjects under weight-bearing test conditions [28]. In current sports medicine practice, rehabilitation and training frequently utilize certain exercises to improve proprioception. The rationale for prescribing such exercises is to prevent unnecessary ligament sprains and joint injuries.

The present study examined whether targeted exercises improve proprioception. Our results show little evidence to support such a contention and suggest that the appropriate experiments remain to be conducted.

Exercises and the ankle

Approximately 4,000,000 ankle injuries occur in the United States every year, one-half of which involve severe sprains [66]. Many ankle injuries occur during sporting activities, and they are one of the most common athletic injuries in amateur and professional athletes alike [25, 47]. Although a recent educational and exercise intervention managed to halve the ankle injury rate in one sport [6], more can be done to prevent ankle injuries. Apart from prophylactic devices, trainers use exercises to prevent ankle injuries. Some exercises are aimed at building muscle strength about the joint, while others seek to improve proprioception at the joint. We examined the rationale underlying the use of exercises for “proprioceptive training” at a joint. Even though we focus here on the ankle joint, our arguments should apply to any joint, including the knee and shoulder, which is the target of proprioceptive training.

One rationale for using ankle exercises is to rehabilitate ankle muscle strength and coordination as quickly and safely as possible following an injury. Typical weight-bearing exercises involve the performance of increasingly challenging unipedal balance tasks, first on a firm floor, then on a compliant surface such as foam, and then on a reduced base of support such as an ankle disc training device [26, 63]. This rationale seems justified if the exercises are aimed at improving motor performance in terms of maximum eversion strength and rate of developing evertor muscle force in order to preemptively prevent unwanted inversion (for example [4]). However, the extent to which such exercises, which involve a particular set of muscles and predictable stimuli, can help to prevent injury caused by unpredictable stimuli in a real life situation is unknown.

In the rehabilitation setting a second rationale given for the prescription of these balance exercises is to improve what has loosely been termed “ankle proprioception” (see, for example, the papers [31, 36, 43, 63] and textbooks [2, 10, 13, 33, 34, 40, 53, 66], which is considered impaired postinjury [8, 9, 20, 22, 69]. However, as we argue below, the use of the term “ankle proprioception” in this context has most often been allowed to include measurement of skill in motor tasks such as balancing, not really true tests of proprioception. In fact, a recent paper from an experienced research team has actually found no impairment in the threshold for detecting ankle rotation after recurrent ankle sprains [56]. In 1997 the American Orthopaedic Society for Sports Medicine and the Foundation for Sports Medicine Research sponsored an Instructional Course entitled “Proprioception, Open and Closed Kinetic Chain Exercises: Implications to Assessment and Rehabilitation with Emphasis on the Lower Extremity,” which clearly infers that such balance exercises improve proprioception. However, as one of the Mayo brothers once said, “understanding must come before belief in medicine.”

We argue here that belief has indeed come before understanding when it comes to the effect of exercise on proprioception. Indeed, it may be premature to conclude that such exercises can improve true proprioception in terms of the two classic proprioceptive modalities: accuracy of joint position sense or the threshold for detecting joint movement (see below). This is because the relevant experiments have yet to be performed to prove or disprove the hypothesis that training improves joint proprioception. We do not dispute that these rehabilitative balance exercises improve balance performance in specific tasks; our point is that the resulting outcome should be stated in exactly those terms – as improvement in balance performance (as, for example, in [21, 26]), not as improvement in “proprioception.” We believe that ascribing any part of that improvement to improved kinesthesia or proprioception remains premature.

This lack of evidence for an effect of training on proprioception is due to the exercise interventions noted above. Although designed to “improve ankle proprioception,” invariably the exercises incorporate a motor task into the methods used for evaluating the outcome measure(s). Consequently, while an improvement in the performance of such tasks is often ascribed to an improvement in sensory function, it can equally well be ascribed to an improvement in motor function without any proprioceptive improvement. However, an improvement in both sensory and motor function and the adoption of a different behavioral strategy remain viable alternative explanations. Because the relative contributions of each of these factors to improving task performance have yet to be documented, it is therefore premature to conclude that such exercises “improve proprioception.”