"The Effects of Proprioceptive Training on Injury Prevention and Rehabilitation"

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ABSTRACT

Objective: The purpose of this literature review is to compile literature and organize it in such a manner to explain the relationship between proprioception and balance training their use in general patient care. There will be two major subjects emphasized throughout this review concerning patient treatment. The first topic discussed will be injury prevention in the elderly population. The second will be post-trauma rehabilitation and treatment, using ankle sprains as an example for injury care.

Data Collection: Resources gathered include referenced journal articles, textbooks and Internet web sites. All sources were searched and gathered at Logan College of Chiropractic's resource center. Pubmed, Mantis and a general card catalog search were used to locate all publications.

Results: The keywords proprioception, balance, chronic ankle sprains, geriatric exercise and tai chi lead to a wealth of publications aimed at improving patient movement specificity and unconscious kinematics. Resources were then placed into groups based on information provided. Basic proprioception and neurology information, geriatric fall prevention, athletic injury treatment, and types of proprioception training were the four basic divisions. Some literature was utilized in more than one area.

Conclusion: This review finds that proprioception plays a vital role in many aspects of patient response to treatment of injury and in the prevention of such injuries. Literature reveals that proprioception and balance training can in fact prevent falls in the elderly population through improved motor reaction. Also, in reference to athletic injury treatment, proprioception training is a valid method of treatment protocol with goals of re-establishing neural control in the injured area, preventing further injury and improving athletic performance and agility. If these ideals are adapted to encompass the treatment of all patients, not just the elderly and athletes, response to treatment and decrease need for treatment may increase.

Key Words: proprioception, dysafferentation, nociception, mechanoreception, balance, wobble/rocker board, chronic ankle sprains, tai chi, geriatric fall prevention, injury prevention

INTRODUCTION

The word proprioception stems from the Latin words "ception" (the act of receiving) and "proprius" (one's own). The concept of proprioception introduced in 1906 by Sir Charles Sherrington (1). By today's definition proprioception is "the ability to sense the position, location, orientation, and movements of the body and its parts. (2)" This is possible by the transmission via multiple types of afferent neurons from the peripheral area of the body sensing the input to the brain which receives the information and processes a request for efferent bodily action.

There are two different types of afferent receptors, which activate during proprioception, nociceptors and mechanoreceptors. Nociception is the perception of pain. These cells may be activated by various stimuli including mechanical, chemical and thermal. Nociceptors generally have a high threshold, meaning that it takes a greater stimulus than other sensory cells to make them fire. However, evidence suggests that tissue injury decreases this threshold, thus increasing the incidence of firing and altering neuronal processing. This ability of the nociceptors to become overly excited is termed "central sensitization. (3)." It is thought that decreased proprioception may lead to increased central sensitization and increased susceptibility to pain.

Mechanoreception involves the perception of body position, pressure, and stretch. A few examples of mechanoreceptors are muscle spindles, golgi tendon organs and multiple corpuscles, including Pacini's corpuscles and Ruffini's corpuscles (1,3). These nerve receptors are found in tendons, muscles, ligaments, joint capsules and musculotendinous units (4). Afferent units are concentrated at specific areas of the body

where body position needs to be relayed accurately and quickly for locomotion and adaptation. The areas of highest receptor concentration are the neck, the sacroiliac joints and the soles of the feet (1, 10). These receptor types also convey the information they transport in two different perceptive capabilities: conscious or voluntary and unconscious or reflexive (5). Decreased joint mobility has been linked to decrease mechanoreceptor stimulation. Thus, proprioception declines with injury, non-weight bearing, and immobilization (4). Lephart and Fu describe a paradigm cycle that begins with ligamentous injury, this injury causes concurrent functional instability and proprioceptive deficits. The proprioceptive deficits inevitably lead to decreased neuromuscular control, which then feeds back into functional instability. The functional instability allows for repetitive injury, starting the entire feedback loop again (10).

It is from these conclusions that proprioception training and treatment would address both injury prevention and treatment. Prevention would occur by improved balance and movement patterns via neuroplastic changes primarily in the dorsal horn and cerebellum. Emphasizing movement and joint proprioceptor re-education could facilitate treatment outcome. From a physician standpoint, this indicates a major need to address not only the abnormal joint complex function but also the residual dysafferentation (3). Meaning that movement needs to be restored and proprioception re-education should be addressed so the afferent nervous system is functioning optimally. This idea could be applied to all joints of the body, however for the purposes of this paper, the ankle will be used as an example. This paper will relate proprioception training to the prevention of falls in the elderly and the treatment of ankle injuries.

As mentioned before, proprioception decreases with injury, non-weight bearing and immobilization. This can be interpreted as the decrease of activity that comes with aging, which in turn decreases weight bearing and mobilization and the increase incidence of injury with specific activities, such as terrain hiking or other athletics. Proprioception training in injury prevention would be aimed at preparing the unconscious mechanoreceptors to trigger reflexive stabilizing muscle contraction during unpredicted position changes. An article printed in December 2004 American Journal of Physical Medicine and Rehabilitation state that "proprioception is the most important function for the reflex adjustment of posture (9)." Injury rehabilitation would be aimed at improving the function of both the conscious and unconscious receptors for both further injury prevention and restoring proper joint mechanics during the specific physical activity.

Proprioception prescription is often given in terms of balancing activities based on patient starting abilities and prior injury. Balance has an integral association with proprioception, as balance is a basic coordination of three systems, the visual system, the auditory system, and the proprioceptive afferent system, therefore any balance exercises are also considered useful for improving proprioception. To enhance and focus on pure neuromusculoskeletal proprioception, patients may remove the auditory and visual systems as their balance and proprioception improves. This topic will be more developed as training prescription is discussed.

DISCUSSION

Proprioception and Falls in the Elderly

Research in recent years is proving that proprioception and balance training in the elderly, particularly those suffering from vascular accidents is proving beneficial in decreasing the number of falls (6,7,15). This is important to note not only from a caring physician standpoint but also from an economic view. Falls are the sixth leading cause of death of Americans over the age of 65 and costs related to such injuries are expected to soar to $32.4 billion by 2020 (6). It has been found that 30% of retirement community-dwelling adults fall at least once a year, with this number taking a significant spike when a previous stroke has been reported (7). This population also has a 7-fold chance of experiencing a fracture during a fall, which can prove catastrophic, as hip fractures are a leading cause of death in the elderly population (7).

Other specific patient populations such as Parkinson's and Alzheimer's disease are thought to be prone to injuries related to proprioceptive deficiencies (9,14). The abnormal tremulous movements in Parkinson's disease are thought to be strongly associated with deficient proprioception abilities (9). Also, the previously mentioned stroke patients would benefit from proprioceptive exercises to increase balance control and improve movement coordination. A study done by the Institute of Preventative Medicine in Copenhagen, Denmark found that subjects scoring better in balance exercises reported higher levels of activities of daily living and overall general physical activity (16). By improving balance and coordination of target population via

proprioception and balance training, activities of daily living and an overall increase in the quality of life may be experienced (11). Prior to understanding how we can prevent injury, we must first understand what factors predispose patients to becoming injured. As of today's literature there are two factors that influence injury, these being intrinsic, or patient related, and extrinsic, environment related (25,26). Intrinsic, or host factors that may affect balance may be things such as dizziness, confusion, or sedative use. Extrinsic environmental factors are conditions such as low lighting, a slick floor, and obstacles to dodge (26). All of these scenarios must be considered when discussion proprioception loss and rehabilitation, as most falls are a combination of multiple factors.

Loss of proprioception in the older population may stem from an overall decrease in neural transmission throughout the body or it may stem from pathologic peripheral neuropathies such as those from Diabetes or Charcot joints (21). However, active populations are generally thought to maintain their health, functioning capacity and activities of daily living for a prolonged period of time (12). In knowing that reaction times to physical stimuli are often shorter than reactions to visual or auditory stimulus, it would indicate that if somatic response could be trained to operate at a heightened level less reliance could be placed upon visual and auditory senses which also decline with age (13).

It is from this information that an inference can be made that continuous balance and proprioception training programs could beneficial in decreasing the number of falls elderly person's experience and the severe disability that often accompanies fall related injuries.

Two Options for Geriatric Proprioception/Balance Training Programs

As mentioned above, geriatric exercise programs show increases in daily activities of living across the board. However, those that utilize balance in their complete regimens tend to produce better results at preventing falls by decreasing response time than physical exercise alone (i.e. walking) (17, 19).

One beneficial activity for improvement of proprioception is the ancient Chinese art of specific, controlled movement called Tai Chi. Tai Chi has been shown to increase kinesthetic awareness, proprioception, and overall stability (17, 18). A study done by the Oregon Research Institute in Eugene, OR found that "the risk for multiple falls with a specific Tai Chi program over 6 months was 55% less than that of the control group performing only stretching exercises (20)." Another study indicated that in patients with vestibular injuries, Tai Chi improved whole body stability and lower extremity stability without improving their gaze or visual stability (21). This indicates that patients adept at performing Tai Chi and similar exercises can rely on non-visual input to improve muscle activity specificity. There are many sources for learning Tai Chi, including books and home videos. However, most individuals would benefit from learning from an experienced instructor in their community, particularly those individuals who may be prone to falls.

Aside from Tai Chi, there are specific exercises one can master to improve balance and proprioception and prevent falls and injuries. A beginning geriatric balance program should first be performed in a safe environment, preferably a health care practitioner's office under close monitoring. It is recommended that as balance is relearned all three sensory afferents are allowed to process without intervention. This

means that the visual, somatosensory and vestibo-auditory systems are all available for patient perception (22). To focus on proprioception, as balance improves, remove the visual system and perform the training again. After this improves, remove the auditory system and leave vision available. When balance activities have been mastered without hearing or visual input, both maybe removed for pure proprioception training. For the purposes of this paper and training in preventing falls, we will assume that the patient population is healthy and without any severe neurological deficit. However, due to pre-existing neurological conditions, in many geriatric populations, progression to the proprioception somatosensory only level is not likely (22).

An example of a balancing program may be to stand in a normal, comfortable position for one minute without any abnormal motions. After it is obvious that there is no gross motor dysfunction during regular stance, the patient should attempt a tandem, or toe to heel, stance for as long as possible (24). When this is accomplished for one minute with ease, a one-leg stance with eyes open may be attempted. After one minute of successful one-leg or pelican stance is mastered the program should be repeated with a less stable surface, such as a sports mat or foam platform. As the program continues, patients should progress by repeating the entire previous process with their eyes closed, thus relying more on pure somatosensory input than visual cues. Other options for advanced proprioception work could take place on rocker boards or balance boards, requiring more recruitment from various muscles. In geriatric fall prevention, this program should accompany an exercise program that may include walking and strength training adapted specifically to each patient.

Treatment of Ankle Sprains Utilizing Proprioception Training

It is true that when it comes to the pain of a sprained ankle, acute symptoms may dissipate quickly. However, residual effects, such as weakness, from ankle sprains may last up to 18 months in a majority of patients (25). This is significant because ankle weakness and loss of kinesthetic properties pre-dispose the patient to further injury or the development of chronic functional instability (1, 27). It has been found that 34% of patients with recent ankle sprains were unable to balance on the injured foot without visual support (28). There is a need for proper rehabilitation after first time ankle injuries because chronic ankle pain and instability cam occur in up to 50% of repeat injuries (27). Proprioceptive loss after injury leaves the ankle highly susceptible for future injury and the entire body more reliant upon other balance cues. A prolonged period of instability is often caused by lack of proper re-training of the area of injury.

Aspects of rehabilitating the unstable ankle are very similar to that of preventing falls in the elderly. However, first the acute symptoms of the injury must be treated and range of motion must be restored. While the patient is non-weight bearing, kinesthetic joint positioning exercises should be performed. An example of this is having the patient utilize foot motion while trying to spell the alphabet with their big toe. As this becomes easier and weight bearing is near, mirroring exercises of the feet may be performed with the eyes closed (23).

While ideally the injured athlete could perform the balance training with no braces or sleeves for support, initial use may provide psychological benefits, if not forced stability (23). Swelling, which promotes stiffness or decrease in motion has been shown to lead to loss of stability (31). Prior to proprioception training while allowing for a

decrease in swelling, air casts have been found to be valuable. However, their utilization should only happen up to 10 days post injury (30). Along with initiating non-active proprioception stimulation via skin receptors, initial ankle bracing also prevents the ankle from over-inversion, which is a likely cause of the vast majority of ankle sprains. After the patient can tolerate standing, balancing proprioception exercises may be started. This should be initiated as soon as the patient can tolerate the exercises in full weight bearing (29), as to prevent future injury with excess activity and instability of the injured joint.

In the athlete, we must also consider that balance training to facilitate normal walking circumstances may not be enough to prevent injury, as the physical demand on their body is much higher than the average person. Thus, a balance program starting with the basic proprioception exercises stated in the fall prevention section should develop into an advanced agility and plyometrics programs (23). Houglum mentions in Therapeutic Exercise for Injured Athletes that there are three ABC's of proprioception training: agility, balance, and coordination. Houglum also mentions that athlete proprioception rehabilitation has a specific progression. Rehabilitation activities should progress from "easy to difficult, from static to dynamic, from slow to fast, and from simple to complex (23, p. 283)." This is important to note, as towards the final stages of rehabilitation, the activities should be sport or activity specific.

General Treatment for Proprioception Re-education Following Trauma

As mentioned earlier, the initial prescription of an athletic proprioception training program should mimic that for fall prevention, by varying stances on a solid surface and progressing to an unstable surface. After these positions are mastered, foam rollers will

be balanced on with different goals at hand. Beginning with exactly the same stances, first regular, then unipedal, and then tandem. Initially, the patient may need assistance before they are able to complete the entire minute on their own. After initial stances are mastered on the roller, specific exercises should be attempted in sets, starting with the squat. The squat will require the patient to utilize the upper extremity to maintain balance. (23)

As the athlete progresses on the foam, another unsteady surface is brought in such as a wobble board or trampoline. Similar stances are performed on the wobble board until a specific level of comfort is reached. After the athlete has mastered to an advanced level, a distraction is added such as catching and throwing a ball at different levels while maintaining the stance. As mentioned before, this should be added only when balance during the stance itself has been discovered (29). The athlete should be discharged from care to return to full activity only when the ankle has recovered at a level of 80-90%.

After proprioception training is complete, athletes should move on to more aggressive forms of agility training. These movements should be proceeded to with care, as they may have triggered the initial injury.

Agility programs utilize intrinsic muscle proprioception development. Examples of such programs are a lateral slide board; restrictive elastic tubing/band movement performing jumps and hops in varying planes of direction; and plyometric activities. Without the use of special equipment, hopping can be a quick and easy method of preparing the injured athlete for re-entry into sport and also re-conditioning the aerobic system (23). Initially, forward and backward hopping should take place until the athlete feels comfortable with lateral movements and confident that the ankle is stable enough to

tolerate such movement. After enough stability is present, progresses to a cross pattern hop and a side-to-side one-foot hop may occur. Various combinations of hop patterns, such as zig-zag, varying length, or circular can be used during the progression to ingrain the correct ankle position and prevent further injury. After the ankle is deemed stable enough, side shuffles, side cross steps, and plyometrics may be tried.

Plyometrics routines are thought to improve muscle strength and endurance and decrease the time for acceleration with change of direction (32). While these exercises are not directly aimed at improving proprioception, it is inevitable that their use will have an effect on somaosensory afferents. Care should be taken with plyometric prescription, as it has been found that cutting maneuvers increase the stress on joints and may allow for ligament injury if not progressed slowly and with care (33). Because there are such a wide variety of plyometric options for training, prescription will not be discussed in further detail for this paper.

CONCLUSION

In reviewing proprioception and relating it to two very different patient populations, it is clear that proprioception re-education is a vital and necessary part to develop through all aspects of patient care. Also, due to the lack of necessary equipment for basic proprioception exercises, exercises may be performed at home with little experience, minimal expense, small space requirements, and at convenient timing for the patient. All health care practitioners should consider the benefits of initiating a proprioception-training program with patients of all activity levels.

Proprioception research has also been compiled examining knee and shoulder injuries. These findings also mimic those of the ankle stating that injury has profound effects on joint proprioception (34, 35). From this we can infer that proprioception retraining of the knee and shoulder/upper extremity could also be utilized to prevent and treat specific injuries.

Research also shows that patients of all ages benefit from very similar exercise programs applied in different situations but for similar goals at hand. While the level of proprioception development may not reach similar levels due to age and physical limitations, the neuropphysiological idea of cortical input via somatosensory afferents influencing balance and motor activity is the same in both elderly and young active populations. This emphasizes that regardless of current patient activity, a proprioception-training program would be benefitial in the treatment and prevention of multiple injuries.

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