***Honors Thesis*:**

Testing the Validity of the InjurySway App and Vibration's Effect on Shoulder Control

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Abstract

Upper extremity stability is critical for injury prevention. Vibration may improve proprioception, reducing injury risk. Mobile applications are accessible reliable tools to measure recovery in athletes. One research purpose investigated whether the InjurySway iPhone app is a valid measure of upper extremity proprioception. The other was whether an acute bout of shoulder exercise performed with an inexpensive vibration toy improves shoulder position sense. Each session, the subject held the phone on the palm, arm forward for 20 seconds both arms. Each subject then completed a Full Can exercise set with the randomly assigned Bumble Ball state (vibration/no vibration) and repeated the app stability measure. Subjects completed a session with the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST). Subjects assumed a pushup position and alternated touching two pieces of tape, 36 inches apart for 15 seconds. Thirty subjects (age 18-22) completed three trials. There was no correlation between path lengths of the conditions and CKCUEST touches. There was a significant decrease in sway over time for both conditions, but no significant difference between the two. Therefore, the Full Can exercise bout decreased sway, but vibration did not contribute to a significant difference. The InjurySway app is not a valid proprioception measure.

Introduction

Proprioception is the awareness of the body in space, referring in particular to the afferent information received from mechanoreceptors (Proske and Gandevia, 2012). Because proprioception plays an integral role in the motor response, it is essential to target less functional areas in athletes to prevent injury. A combination of preseason strength, fatigue and functional testing was successful to identify football players who would sustain a shoulder injury during the season (Pontillo, 2014). This important finding reveals the need for testing prior to competition to determine players who are at risk for injury, suggesting that remediation can lessen injury risk. As an example, a relationship exists between dynamic balance performance, which is a measure of sensorimotor function and concussive injuries. In a study of elite male rugby union players, researchers found that the players who had exhibited poorer dynamic balance performance before the season had three times the risk of sustaining a sports-related concussion, even after controlling for history of concussion (Johnston, 2018). These findings reveal the need to target sensorimotor functioning to prevent injury.

Strengthening of the rotator cuff muscles, especially the supraspinatus muscle, is an essential part of rehabilitation for athletes presenting with shoulder problems. The tendon of the supraspinatus muscle is most frequently injured because of its vulnerable position between the humeral head and acromion. Rehabilitation exercises to improve rotator cuff strength target the supraspinatus (Boettcher, 2009). This is especially true for athletes competing in overhead throwing sports, such as baseball and softball. A study aimed to investigate the most effective exercise to strengthen the supraspinatus muscle for rehabilitation purposes found that the empty can and full can exercises were most effective in activating the supraspinatus muscle (Takeda, 2002). Both have subjects abduct their arm to 90° in the scapular plane with thumb up or down.

Prior research indicates that vibration is an effective tool to increase neuromuscular performance (Ashnagar, 2016). In particular, whole body vibration induces length changes in muscle groups, stimulating primary endings of muscle spindle receptors that cause reflexive contraction. The addition of these reflexive contractions to a voluntary skeletal muscle activation, such as the Full Can exercise may increase neuromuscular performance. Researchers found that a short exposure to whole body vibration increased the surface electromyography activity of the upper extremity muscles in a static modified push-up position (Ashnagar, 2016). Other researchers found that postural changes caused by delayed onset of muscle soreness disappeared following vibration therapy that decreased pain perception (Iodice, 2018). Local vibration training can be an alternative to whole body vibration that directly targets specific muscles and is a more portable method. Local vibration stimuli have the potential to act as a significant neuromuscular workload by inducing some fatigue, which could trigger long-term neural adaptations that leads to improved functional performance (Souron, 2017). Therefore, vibration therapy is an effective method to target weak functioning areas in athletes to prevent injury.

Humans depend on proprioception as a signal to respond to the environment and changing circumstances. Proprioceptors provide information about position in three-dimensional space that is separate from visual information so we have another venue for response. Proprioceptors are concerned with conscious sensations, which include the senses of limb positions and movement, the sense of tension or force, the sense of effort and the sense of balance (Proske and Gandevia, 2012). These provide for sensorimotor control needed for central nervous system control of movement, balance, posture and joint stability (Röijezon, 2015).

Therefore, impaired proprioception is detrimental to sensorimotor control and can be caused by gradual-onset musculoskeletal pain disorders, trauma and muscle fatigue (Clark, 2015).

The sensorimotor system includes all sensory and motor components, with central integration and processing systems involved in maintaining joint homeostasis during bodily movements (functional joint stability). Since stability is desirable, targeting proprioception is important to organize muscle activation for sensorimotor control of functional joint stability (Riemann and Lephart, 2002). In sum, receptors in the skin, joints, muscles, tendons and visual and vestibular systems receive stimuli from the environment, which creates an afferent pathway to the central nervous system. The spinal cord, lower brain and cerebral cortex are all components that send a message via an efferent pathway to the muscles, contributing to a motor response. Therefore, proprioception is an essential concept to study in the context of musculoskeletal injury.

The stability test used in this research is the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST). This test fulfills a need for functional testing of patients as a rehabilitation tool, providing objective data to determine whether a patient is ready to return to play. The ideal test is easy to perform and requires little equipment and space. In this test two pieces of tape are placed on the ground, parallel to each other 36 inches apart. The subject assumes a pushup position with one hand on each piece of tape and is instructed to remove one hand from the floor, touch the opposite line and replace the hand on the original line. The subject alternates this movement between both hands for 15 seconds, and the number of touches achieved is documented. Previous literature indicates that this test is a reliable evaluation tool, and thus can be used for its intended purpose (Goldbeck and Davies, 2000). This test was also found to be valid, correlating with risk of injury (Goldbeck and Davies, 2000). Mobile

applications can also serve as a rehabilitation tool. With the increasing amount of technology, mobile applications will be an excellent measurement tool widely available to clinicians. In athletics, it would be beneficial for athletic trainers to have access to mobile applications to test athletes for objective data that aids in the rehabilitation process.

Through this abundance of research, it is clear that proprioception is important in sensorimotor control and thus essential for athletes. Preseason testing of athletes can reveal those at more risk of sustaining an injury (Pontillo, 2014). This reveals a need to target these areas in athletes to prevent injury, which can be done using vibration methods. In cases where prevention isn't possible, functional tests and measures will assess an athlete's progress in rehabilitation. Athletic trainers strive to ensure that athletes are released to play at the appropriate time to maintain progress and prevent an injury from escalating. Therefore, it is beneficial to provide these clinicians with tests and measures to obtain objective results to make their decision process easier and more valid.

The supraspinatus muscle is important for overhead athletes such as baseball, softball or tennis players. Targeting this muscle in rehabilitation is important and thus a need for measures to assess and improve functioning. The Full Can exercise is effective in targeting this muscle and the CKCUEST is reliable in assessing stability of the upper extremity. The ability to use a mobile application to assess the progress of an athlete will be beneficial as it will be widely accessible and easy to use for clinicians.

The main purpose of this research is to 1) determine whether the InjurySway iPhone app is a valid measure of upper extremity proprioception and 2) determine if the 144 Hz vibration of the Bumble Ball impacts the upper extremity stability of subjects, measured by the path length of sway by holding the iPhone. The Bumble Ball is a child and dog toy that is powered by a

motorized box with batteries. Turning the switch on causes the ball to vibrate. Subjects will alternate whether they use the vibration of the Bumble Ball or not for each of their visits. The results determine if this application can be used alongside vibration exercises such as the Full Can exercise in rehabilitation programs for athletes with shoulder injuries to assess their progress and ensure recovery and return to play. Traditional vibration methods may be expensive and require a significant level of skill by the technician, indicating the usefulness of a simple vibration tool such as the Bumble Ball, if successful.

Methods

Subjects

Thirty college students (22 female) volunteered to participate in the study with an average age of 19.9 years (range 18-22). The average weight was 62.203 kg (13.098 std dev), average height was 1.693 m, and average BMI was 21.526 kg/m^2. The activity levels of each participant are shown below in Table 1. Twenty-three participants are right-handed, 6 are left-handed and 1 is ambidextrous. The subjects were instructed to maintain current daily activities and workout programs. Subjects were excluded if reporting a musculoskeletal injury in the last 30 days. All of the subjects read and signed an informed consent form, which was approved by the Florida Southern College Institutional Review Board, before participating in the study.

Table 1. Activity levels of each participant

Activity Type	Number of Participants
Recreational Running	6
Basketball and Baseball	1
No Sports	4
Cross Country and Track	13
ROTC	1
Cross Country, Track and Swimming	1
Volleyball	1
Weightlifting and Track	1
Track	2

Procedure

Each participant completed three sessions with one day in between each. For each of the three visits, subjects warmed up by self-paced jump roping for five minutes. The InjurySway app was then used on both hands, with the dominant hand first. The subject stood in an upright position with the arm placed fully in front to be parallel to the ground with the phone on the palm of the hand. The subject closed both eyes and followed the protocol of the app, holding the phone as still as possible for 20 seconds (Figure 1). The subject then completed shoulder exercises using both arms, with the dominant arm first. The subject completed the exercise with or without vibration of the Bumble Ball (www.chewy.com) on the first visit and then alternated for the remaining two visits. The subject alternated arms for the exercises to complete a total of 3 sets of 15 repetitions for each arm. The exercise completed was the Full Can/Scaption exercise. The subjects stood with both arms at the side and raised one arm to the side at 30 degrees with arms neutral and thumbs pointing up. The arm was lifted to eye level, briefly held and slowly lowered to starting position (Figure 2). The app was then used again on both hands, with the dominant hand first, using the same protocol as before. Each visit ended with the completion of the Davies Closed Kinetic Chain Upper Extremity Stability Test. The subject was asked to demonstrate a pushup position with their hands on two different pieces of tape 36 inches apart.

When the examiner said begin, the subject removed one hand from the floor, touched the opposite line and replaced the hand on the original line. This was repeated with the other arm and the number of touches achieved in 15 seconds was documented (Figure 3).

Figure 1. Demonstration of the InjurySway app protocol

Figure 2. Demonstration of the Full Can Exercise with the Bumble Ball

Figure 3. Demonstration of the Davies Closed Kinetic Chain Upper Extremity Stability Test

Statistical Analysis

Prior to ANOVA analyses, all data were assessed for normality, homogeneity of variance and sphericity assumptions. If the assumption of Mauchly's sphericity test was violated, a Greenhouse-Geisser correction was applied (Greenhouse and Geisser, 1959). Following, a 2-way repeated measures ANOVA was used to determine the effect of condition (vibration, no vibration) over time (pre, post) on sway score. Significant main effects were examined using paired t-tests. Partial eta squared (η_p^2) was used to assess effect size. Paired t-tests were also used to determine differences in the number of touches performed following vibration and no vibration conditions. Lastly, validity between mobile application (sway score) and the Closed Kinetic Chain Upper Extremity Stability Test (touches) was assessed using the Pearson Product Moment Correlation (r). Significance was defined a priori at $p \leq 0.05$. All data are reported as mean ± standard deviation (SD). All statistical analyses were completed using IBM SPSS (Version 26, Armonk, NY, USA).

Results

There was a significant ($p=0.009$ and $\eta_p^2=0.27$) main effect of time. The Full Can exercise contributed to a decrease in path length/sway in both the vibration and no vibration conditions. However, there were no significant ($p>0.05$) 2-way interactions between condition and time. Therefore, there was no significant difference in path length between the vibration and no vibration conditions. The use of vibration in the Full Can exercise did not contribute to a significant difference in path length/sway (Figure 4). In line with this finding, there were also no significant ($p>0.05$) differences in the number of touches performed between vibration and no vibration conditions (Figure 5). There was no correlation ($r=-0.179$, $p>0.05$) between the path length and number of touches performed in the vibration condition. There was also no

correlation (r=-0.066, p>0.05) between the path length and number of touches performed in the no vibration condition. This indicates no validity in using the InjurySway app to measure upper extremity proprioception.

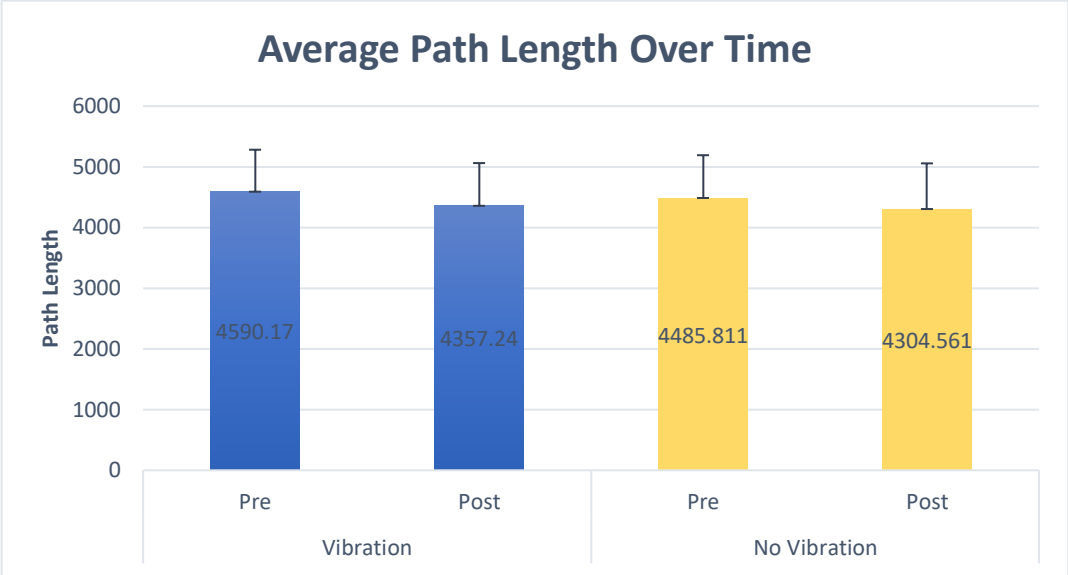

Figure 4. There was a significant (p=0.009 and η_p^2=0.27) main effect of time such that the Full Can Exercise contributed to a decrease in path length/sway in both conditions. There were no significant (p>0.05) 2-way interactions between condition and time, indicating no significant difference between conditions.

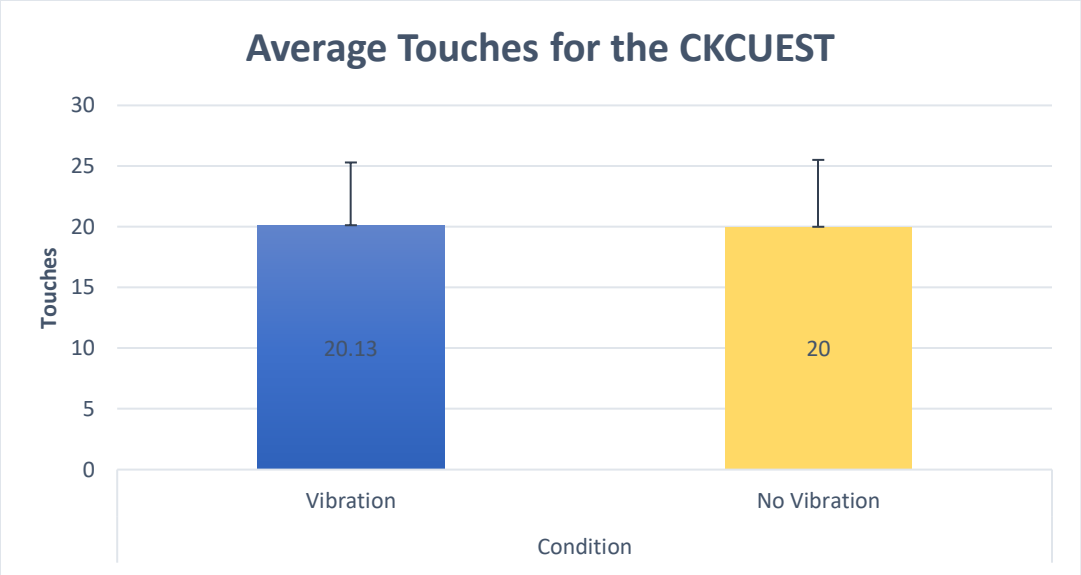

Figure 5. There were no significant ($p>0.05$) differences in the number of touches performed between vibration and no vibration conditions.

Discussion

Researchers found no correlation between the number of touches performed by subjects and the average path length values in both the vibration and no vibration conditions. This indicates that the InjurySway app is not a valid measure of proprioception. Since the CKCUEST is a reliable and valid measure, researchers should have found a correlation between this test and the path length values. Although the app does measure path length values, since there was no correlation, these path length values do not accurately measure upper extremity proprioception of subjects. Testing the validity of this app could have been performed without the use of the Full Can exercise bout. This research study incorporated two different research goals that if were successful, could provide clinicians a way to target and accurately measure upper extremity proprioception. However, the exercise bout could have affected the validity measure in this study. Future researchers could avoid this limitation by conducting a study focusing only on

validity of the app. This would be done without the exercise bout and merely measure the path length of the app on both hands of subjects alongside the CKCUEST. A correlation test could be run between these two measures to determine the validity of the app. A greater number of subjects may also strengthen the validity test. This would be a beneficial future study as the ability to use an app such as the InjurySway app would be easy and efficient for clinicians to use.

The average path length obtained from the app decreased after completion of the Full Can exercise with the Bumble Ball in both the vibration and no vibration conditions. This indicates that the Full Can exercise contributes to shoulder control and thus decreased sway/increased balance. However, there was no significant difference between the path length values completed for both the vibration and no vibration conditions. This was also the case for the number of touches completed for both conditions. Therefore, the effect of vibration did not contribute to a significant difference in the ability to perform better on the InjurySway app or CKCUEST, which is a measure of proprioception. The Full Can Exercise is an effective way to improve upper extremity balance control, but the 144 Hz vibration of the Bumble Ball did not contribute significantly to this control compared to the no vibration condition. Therefore, this particular bout of vibration had no significant effect on shoulder control. Prior research indicates that the use of an individualized vibration frequency produces a greater response from the neuromuscular system and is more beneficial than vibrations at a fixed pre-selected frequency. This frequency could be determined by measuring each subjects' electromyography activity (EMG) of the upper extremity muscles (Di Giminiani, 2009). Therefore, an explanation for the results of this study could be that the fixed value of 144 Hz frequency did not significantly help each subjects' upper extremity control. However, if each subjects' EMG could be determined and subjects were prescribed a specific level of vibration frequency, it is possible there would be significant level

of decrease in sway. However, this would be difficult to obtain with a Bumble Ball that does have a fixed value of frequency. Although the Bumble Ball is easy to use and holding it during the Full Can exercise bout did decrease sway, its vibration frequency may be too much or too little to contribute to a significant improvement in shoulder control. Since this study provided the implication that the InjurySway app is not a valid proprioception measure, the results of the exercise bout in this study could have been affected. It is possible that since the app was found to be not valid, indicating that the path length values obtained do not accurately measure upper extremity proprioception, they cannot be accurately correlated with the valid and reliable CKCUEST. Like discussed above, the validity of the app should be measured as its own study. If it was found to be valid, the app could thus be used again in the same study to test vibration's effect on shoulder control. If the study was run again with more subjects and this potential knowledge, it is possible the results could change and indicate a stronger effect of vibration on shoulder control.

Conclusion

Researchers found no correlation between path lengths of the conditions and CKCUEST touches. This indicates that the InjurySway app is not a valid proprioception measure. There was a significant decrease in sway over time for both conditions, but no significant difference between the two. There was also no significant difference in the amount of touches performed between both conditions. Therefore, the Full Can exercise bout decreased sway, but 144 Hz vibration of the Bumble Ball did not contribute to a significant difference.

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