DETERMINING THE EFFICACY OF THE DELOS POSTURAL PROPRIOCEPTIVE SYSTEM AS A PREVENTATIVE TOOL IN A DIVISION I FEMALE SOCCER TEAM

by

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STATEMENT OF THESIS APPROVAL

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ABSTRACT

Proprioceptive training is often utilized in the rehabilitation process after an injury has occurred but is not used frequently enough in preventative efforts. The Delos Postural Proprioceptive System (DPPS) utilizes the combination of an unstable surface and a visuo-proprioceptive component, making it an optimal preventative tool. The aim of this study is to determine the efficacy of the DPPS as a preventative tool in a Division I female soccer team. The intervention is hypothesized to enhance proprioceptive, neuromuscular, and sensorimotor abilities, therefore decreasing risk of injury. Fifteen Division 1 female soccer players at the University of Utah were recruited to investigate the relationship between proprioceptive ability and injury risk in the lower extremity over 14 weeks. We collected baseline data prior to the start of the season, implemented DPPS training sessions twice weekly throughout the season, and conducted postseason testing and collaborated with the athletic training staff to compare lower extremity injuries to the previous season. Observation of injury rate was calculated along with mean change in proprioceptive performance according to DPPS. From the 2016 season to the 2017 season, there was a 25% decrease in noncontact lower extremity injury within the team. Throughout the 2017 season in which training sessions were being performed, both dynamic balance assessment scores improved. There was no significant improvement in the static balance assessment scores. Implementing a proprioceptive training program that emphasizes high-frequency instability and visuo-proprioceptive feedback may have a positive impact on injury rate as well as proprioceptive autonomy.

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INTRODUCTION

According to the NCAA, the overall women's soccer injury rate in both games and practices is 7.3 per 1,000 athlete exposures, with lower limb injuries making up 65.3% of all injuries (NCAA Fact Sheet). While a significant portion of lower extremity injuries in collegiate soccer players occur due to contact with opposing players, there remains a high rate of non-contact injuries due to improper mechanics, lack of stability at the ankle and knee, and other environmental and biological risk factors. Proprioceptive training is a method that specifically addresses this instability, and thus the injuries it may cause. Proprioception can be defined as a specialized variation of the sensory modality of touch that encompasses kinesthesia, the sensation of joint movement, and joint position sense.[1] Many studies have focused on the effects of proprioceptive training in a rehabilitative capacity, specifically for ankle injuries, and it has been shown to be a valuable tool in the rehabilitative process and ultimately improves overall outcomes (Giraldo, Lephart, & Pincivero, 1997; McKeon & McKeon, 2012). Following the model of proprioceptive exercises in a rehabilitative context, it is logical to assume that increasing proprioception and proper mechanics through training will ultimately lead to an improvement in balance and postural control, increased awareness of joint kinesthesia, and increased neuromuscular activity. The combination of these improvements will lead to a decrease in lower extremity injury rate as self-correction in vulnerable positions increases. The Delos Postural Proprioceptive System (DPPS) is designed to enhance

proprioception and lower-extremity stability using visuo-proprioceptive training methods, based heavily on the Riva Method that states “high frequency proprioceptive reprogramming for the recovery of stability and the improvement of efficiency of movement both in athletes and in pathological situations where motor activity is highly compromised (going beyond the limits of classic physiotherapy)”(McKeon et al.). The existing literature on the system is sparse and its scientific reliability as a preventative tool has yet to be established in a variety of contexts.

REVIEW OF LITERATURE

There is evidence in literature to suggest efficacy of the DPPS in decreasing the risk of falls in multiple sclerosis patients, as the system implemented over a 6-week training period improved stability in a single-leg stance (Prosperini, Leonardi, De Carli, Mannocchi, & Pozzilli, 2010). The visuo-proprioceptive training that the DPPS provided led to improved postural strategies for the majority of subjects in this study. While this research demonstrates DPPS's efficacy in rehabilitation of multiple sclerosis and provides valuable information regarding the biomechanical benefits it may yield, it does not establish any suggestion regarding how this system may affect an athletic population without such a debilitating condition.

The most common context for use of DPPS is currently professional men's basketball, as in a prospective study by Riva et al. investigating the effects of proprioceptive training on injury prevention over a 6-year period (Riva, Bianchi, Rocca, & Mamo, 2016). The researchers found that when compared to traditional proprioceptive training methods, the utilization of electronic postural proprioceptive stations (DPPS) led to a significant decrease in lower extremity injury, specifically ankle sprains, knee sprains, and low back pain incidence rate. The authors attribute this decrease to two mechanisms: first, repetitive reflex contraction of stabilizer muscles in the foot that occurs during the high-frequency exercises in the DPPS protocols, and second, the authors noted a cumulative effect of traction forces being imposed on connective tissue in

the lower extremity thousands of times throughout training sessions, thus improving their protective action. This particular study is especially helpful in guiding our research as it demonstrates the specific mechanisms with which the DPPS improves proprioception and subsequently, decreases injury occurrence. However, this study also included traditional proprioceptive training and was focused on professional athletes rather than a collegiate level athletic team.

There is a significant void in the research regarding collegiate athletes and the use of the DPPS specifically in a preventative sense. Existing literature has focused on injury reduction in professional athletes (Riva et al.) and young female soccer players (Giraldo et al.), but these results are not directly translatable to a collegiate athletic population. Overall, the current research available fails to examine the possibility of a relatively short-term intervention of the DPPS preventing lower extremity injuries in a collegiate athletic team. Studies have revealed that among healthy adults, the implementation of proprioceptive training using DPPS reduced the need for external support as well as the risk of falling due to increased proprioceptive reflex responses (Carli, Patrizi, Pepe, Cavaniglia, Riva, & D'ottavi, 2010). However, there are sure to be significant differences between the proprioceptive abilities of healthy adults as compared to collegiate athletes, especially in a sport such as soccer which is heavily focused on unilateral control and lateral movements. Even within soccer, dynamic balance and proprioception vary across competition levels, and movement strategies will have varying weaknesses and strengths depending upon years of experience in the sport (Butler, Southers, Gorman, Kiesel, & Plisky, 2012). This variation suggests that research conducted on adolescents or professional athletes in their late 20s and early 30s will not necessarily translate to the

collegiate population, and specific studies involving this population must be conducted in order to establish efficacy of this particular prevention method.

Aim of Study

The aim of this study was to investigate the efficacy of the DPPS as a preventative tool for lower-extremity injuries in a Division I women's soccer team. It was hypothesized that the implementation of DPPS training into the regular training and practice regimen for the team would improve postural control and encourage proper mechanics in vulnerable circumstances, thus leading to a decrease in noncontact lower extremity injuries as compared to the previous season. It was also hypothesized that this improvement would be demonstrated by higher postintervention balance assessment scores than what was demonstrated preintervention. With confirmation of this hypothesis, a basis and a template can be established for further use, specifically at the University of Utah, and eventually on a larger scale.

METHODS

Participants

Thirty Division I female soccer players at the University of Utah, of all positions, ranging from 18-25 years of age were recruited to participate in this study. Informed consent was received from each participant and institutional review board approval was granted by the University of Utah. All 30 athletes completed the preseason baseline assessment; however, throughout the season approximately 15 participants failed to comply to the necessary training sessions and were subsequently excluded from the study. The present study includes 15 soccer players that completed all of the necessary assessments and training sessions. Participants were required to be on campus four weeks prior to the beginning of their preseason training schedule as well as throughout the season and one month following the conclusion of the season. Participants who suffered an acute lower extremity injury, underwent lower extremity surgery within the last 6 months prior to the study, sustained a concussion in the 2 weeks prior to the study and/or were under concussion protocol were excluded from this study. In the case of a lower extremity injury occurring within a subject during the duration of the study, data were collected to the subject's tolerance and were sorted into a separate category than the healthy athletes. However, the only athlete that sustained a lower extremity injury and required surgery within the timeframe of this study did not complete the postintervention baseline assessment and was therefore excluded from the data. Baseline data as well as

progression data were collected for each participant to track progress in the training sessions and provide indication for progression to the more difficult protocols.

Study Design

The independent variables within this study are the Delos Postural Proprioception System training that occurred in conjunction with the team's regular conditioning, practices, and competition, and the baseline tests for each athlete, which took place prior to the intervention and immediately following the conclusion of the season. The primary dependent variable within this study is lower extremity injury occurrence as compared to the previous season. In addition, as a secondary dependent variable, we evaluated postintervention balance assessment scores for each athlete as they related to preintervention baseline scores. Evaluating the two scores allows a clear picture of progress in terms of proprioceptive autonomy and static and dynamic postural stability.

PROCEDURES

The Delos Postural Proprioception System (DPPS; Delos, Turin, Italy) was used for all baseline stability testing. The DPPS equipment and all associated software (DPPS 5.0) are located in the athletic training room at the University of Utah (Figure 1). This software is displayed on the laptop it is installed on as well as a larger output monitor for the subject to view. The DPPS consists primarily of the Delos Equilibrium Board (DEB), which rotates to allow 15 degrees of motion in both the medial and lateral and anterior and posterior directions, and the Delos Vertical Controller (DVC), which is strapped onto the subject's chest during testing and training to detect trunk movement and record postural stability. At waist height for the subject there is also an infrared sensor bar (ISB) that serves to reduce the risk of falls during testing as the subject is able to use the bar for additional stabilization. This bar also serves to record increased instability as it measures how long the subject uses it for additional assistance.

Data collection primarily consisted of two proprioceptive balance assessments for each athlete throughout the study: preintervention and postintervention. The initial baseline measurements were taken prior to the start of preseason team training and involve both static and dynamic components. The static test requires the athlete to stand on a flat board in a monopodalic stance, one trial with eyes open and one with eyes closed. This test measures precaution (subject using stability bar, unable to maintain stance without external support), visual dependence, proprioception, and vestibular

strategies. The dynamic test measures the aforementioned components as well as visuo-proprioceptive strategy, which tends to allow for more refined postural control. The Delos system expresses proficiency in these assessments in terms of a Stability Index (SI), which is a composite of the number and duration of errors made by the athlete and her ability to maintain postural control throughout the assessment. If the dynamic tests are performed correctly, the majority of movement will occur at the lower extremity in the form of high frequency adjustments to maintain position, rather than at the trunk that will remain stable. Each baseline test for each athlete required 20 minutes including setup and calibration of the system.

The second phase of this research consisted of 12 weeks (the duration of the season for the team) of DPPS training sessions twice per week. While the primary researcher was present during initial baseline testing, athletes were given instruction regarding the proper use of the system and the basic movements required for the training sessions and performed training sessions independently throughout the 12-week period. Participants began training on the Ute 1 Program on DPPS, which was specifically designed for athletes at the University of Utah. The Ute 1 Program involves both the right and left limb and consists of 16 total trials in both the lateral and anterior and posterior directions. The first four trials (two for each limb) were completed with the eyes open, and the board positioned to move laterally for 20 seconds as the athlete attempts to remain centered and balanced on the board. The next four trials were completed in the same way, with the eyes closed. The next eight trials were completed in the same way, four with eyes open, four with eyes closed, alternating right and left, but the board was positioned to move anterior-posterior. All 16 trials lasted 20 seconds and allowed a rest

period in between, ranging from 5-30 seconds, depending on the fatigue of the athlete and the time required to reposition the board.

Data were collected every 2 weeks throughout the duration of the 12-week intervention period in the form of proficiency statistics extracted from the training sessions. These data allows us to evaluate each athlete's stability index in both the anterior-posterior and lateral directions. If athletes were injured during the study, these data were utilized to differentiate between the healthy group and the injured group. The final baseline test was conducted at the conclusion of the season (postintervention) and the results were compared to preintervention baselines to assess whether there was an improvement in proprioception throughout the intervention. The baseline testing also allowed us to analyze postural sway during testing and foot position measured in degrees of supination and pronation.

Statistical Analysis

Paired samples *t*-tests were used to examine the change between three pre and postassessment values (static eyes closed, dynamic unconstrained, and dynamic constrained) related to proprioceptive control and autonomy in terms of the Stability Index. Statistical significance was established at $p \leq 0.05$. Noncontact lower extremity injury incidence was observed, in addition to time lost and the nature of the injuries sustained and compared to the previous season.

Figure 1. The Delos Postural Proprioceptive System and associated equipment.

RESULTS

Our primary hypothesis regarding noncontact injury incidence was confirmed in that we saw a decrease in noncontact lower extremity injuries that caused time loss when comparing the 2016 season to the 2017 season. In the 2016 season, the team suffered 24 total noncontact lower extremity injuries with a total of 178 days lost as a result of these injuries. In the 2017 season, concurrent with the Delos proprioceptive training sessions, the team suffered 18 noncontact lower extremity injuries causing just 23.5 days lost.

Our secondary hypothesis that training consistently on the Delos throughout a sport season improves postural stability scores was partially confirmed in that the mean stability index for the dynamic unconstrained test improved (70.04±12.75 to 80.71±8.16, $p=0.01$) as well as the dynamic constrained test (71.60±13.95 to 82.71±7.40, $p=0.04$). However, static preintervention and postintervention assessments did not see a significant improvement (81.51±12.56 to 83.49±6.01, $p=0.40$).

DISCUSSION

The purpose of this study was to investigate the efficacy of the Delos Postural Proprioceptive System as a preventative tool in a collegiate athletic context. In order to demonstrate this efficacy, we evaluated the system's effect on both balance assessment scores and noncontact lower extremity injury rate. The most notable finding of this study was the significant improvement in proprioceptive ability across two different measures, even more notably, the dynamic components of the baseline assessment. This improvement suggests that with consistent training on the DPPS throughout a sport season, proprioceptive autonomy and the ability to gain and maintain stability in an unstable environment will improve. Both the improvement of proprioceptive abilities and a reduction in injury rate as a result of balance training is supported in the literature (Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005; Mandelbaum, 2005). The lateral movements that the athlete is counteracting in order to do this are easily translatable to the lateral movements that an unstable surface, such as a soccer field, may require. Engaging the neuromuscular pathways involved in this ability during training reduces the risk of tissue damage and injury in that unstable environment. While the static component of the assessment did not demonstrate significant improvements, static stability is not as sport-specific an ability as dynamic stability, so this is not cause for concern.

It is also worth noting the nature of the injuries that occurred in the 2016 season as compared to the 2017 season. While it is important that the total number of non

contact lower extremity injuries decreased from one season to the next, the difference in number of days lost carries more weight as it directly affects each athlete and the team as a whole throughout the season, and this difference can be attributed to the variations in the nature of the injuries sustained. The 2016 season involved a higher number of days lost largely due to a higher number of ligamentous and cartilaginous injuries that required surgical intervention, while the 2017 season saw a greater number of muscular strains that required minimal days lost and no surgical intervention (see Table 1). Our efforts to utilize proprioceptive training to reduce injury rate emphasizes these traumatic, often season-ending injuries that often occur as a result of an inability to effectively adjust for an unstable, dynamic environment. The way that developing this ability can have a positive effect on the specific injuries that are sustained is evidenced by the differences in injury nature between the two seasons that were analyzed.

While the findings of this study were significant in some respects, the impact of the DPPS was not of the magnitude that we initially anticipated and is not proportional to the challenges it may present in a clinical setting. It is important to consider the variety of reasons that may be responsible for a lack of more significant improvement in the static measures as well as a marginal decrease in injury incidence.

Limitations

The population we were working with presented the first barrier to significant findings: college athletes with chaotic schedules and minimal extra time in their days. Compliance became an issue fairly quickly and proved difficult to overcome throughout the study. Several athletes trained consistently throughout the season, but others were

more sporadic in their training sessions. While this is an internal limitation that can be approved upon in future studies, in a clinical sense, compliance will always be an issue. It is worth considering that a program or system that allows for leniency in compliance while still providing benefits may be more realistic and yield more favorable outcomes. This issue is far less detrimental in professional athletics (Riva et al.) due to the level of control and compliance in the professional environment versus college and even more so in high school athletics. This variation between competition levels creates doubt regarding its efficacy in widespread use and it seems that its benefits may rely on a highly specific context.

The second limitation involves the prior training of the athletes involved in the study. The athletic trainer for this team regularly emphasizes dynamic balance exercises and incorporates the DPPS into lower-extremity rehabilitation protocols, which predisposes these athletes to perform well initially and also precludes them from experiencing dramatic improvements throughout the season. In the future, it may be advantageous to recruit athletes who have minimal prior proprioceptive training as well as minimal to no experience with the DPPS to better assess how the system affects the general athletic population.

Limits of the current study also included the small sample size and the relatively short duration of the study. A longitudinal study over several years with a larger group of athletes would provide a clearer, more thorough picture of the effects of the DPPS on proprioceptive ability and more importantly, injury incidence.

Table 1. Specific injuries and days lost for the 2016 and 2017 seasons.

	Lost Days		**Lost Days**
2016		**2017**	
Connective Tissue		**Connective Tissue**	
L ACL Tear	38	R Knee Hyperextension	1.5
R Patellar Cartilage Tear	81	L Lateral Ankle Sprain	3
R Lateral Meniscus Tear	30	L Lateral Meniscus Tear	14
R Lateral Ankle Sprain	20		
Total	**169**	***Total***	**18.5**
Musculotendinous		**Musculotendinous**	
L Quadricep Strain	4	R Groin Strain	1
R Calf Strain	4	R Groin Strain	1
R Plantar Fascia Partial Tear	1	L Peroneal Tendon Strain	3
Total	**9**	***Total***	**5**

CONCLUSION AND FUTURE DIRECTIONS

The rationale behind the DPPS and the explanation for its benefits is best described as a combination of high-frequency instability imposition and visuo-proprioceptive feedback. The high-frequency instability that is created by the hardware components of the DPPS is more effective than traditional proprioceptive training methods; this is due to its similarities to sport-specific, dynamic situations. The instability that is imposed and the physiological response that occurs in the connective tissue and intrinsic musculature are primarily responsible for the increased ability to make efficient adjustments. The visual feedback connects the sensory and motor systems and allows the athlete the opportunity to make adjustments based on what they see in addition to what they sense at the joint – much like they would in a sport situation. The results of the present study reflect the benefits of these underlying principles as dynamic assessment scores improved and injury incidence decreased over time. Traditional proprioceptive rehabilitation and training are lacking both of these components as there is a high level of variation in what proprioceptive training involves, and oftentimes it is focused more on agility and coordination than dynamic stability and connecting multiple physiological systems (Mandelbaum, 2005).

There exists an ambiguity regarding proprioceptive training and rehabilitation; the literature does not provide specific recommendations in terms of protocols or evidence-based approaches. The principles behind the DPPS are both valuable and progressive as

they reach beyond typical proprioceptive efforts and have been shown to improve dynamic stability and autonomy in several populations; the present study saw significant improvements specifically in dynamic stability and clear progression over time with consistent training on the system. However, the system is relatively expensive and requires training to operate; the output as well as the operation is not user-friendly and may prove challenging to implement in a variety of clinical settings. Future research should begin by focusing on establishing clear, standardized guidelines for proprioceptive training and rehabilitation as the field currently lacks such structure. Beyond that, future research efforts should emphasize finding a method of implementation of DPPS's principles and methods that is more cost-effective, feasible, and allows for the reality of varying levels of compliance for a variety of clinical settings and athletic populations.

S*ummary*

The present study demonstrates that visuo-proprioceptive training on the DPPS is effective in improving dynamic stability assessment scores in athletes from a Division I Women's Soccer team. The implication of this improvement is evident in the decrease in noncontact lower extremity injuries in these same athletes from the previous season to the present. The generalizability of these results requires further evaluation as the DPPS may not be the most feasible method of proprioceptive training across competition levels and clinical settings; however, the mechanisms utilized by the DPPS should be considered in the development of proprioceptive protocols in the future

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