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Clinic-Based Algorithm to Identify Female Athletes at Risk for Anterior Cruciate Ligament Injury

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Response to Methodological Concerns

It is important for us to mention that the goal of our study was to apply the algorithm developed by Myer et al and not to reproduce their earlier development studies or to validate their assessment tool (please see Goetschius et al[4]: “The objective of the current study was to apply the clinic-based algorithm developed by Myer et al”[4(p1979)]).This distinction is vital to understanding our study design, statistical analysis, and the conclusions that were drawn. Myer et al, in their previously published articles, developed a clinic-based algorithm that was designed to identify female athletes at risk for demonstrating a high probability of knee abduction moment (pKAM), with the proposal that those at risk for high pKAM would also be at increased risk for suffering anterior cruciate ligament (ACL) injury.[7–9] Myer et al did not apply their pKAM algorithm to determine its predictive ability to a group of athletes at risk of suffering an ACL injury with the use of a cohort or case-control study. Therefore, our study was the first to attempt to apply the algorithm.

The first set of concerns involved the approach that we used for the drop vertical jump (DVJ) task. Myer et al point out that the DVJ movement task that was used in our study replicated the approach described by Padua et al[10] and expressed concern that it was substantially different from the DVJ employed during the development of their algorithm. Specifically, there was concern regarding the horizontal movement associated with the DVJ described by Padua et al.[10] Myer et al point out that the DVJ, “from which the clinical nomogram was developed, was designed not to incorporate horizontal movements.” The authors posit that this horizontal movement associated with the DVJ may affect frontal plane measurements such as dynamic valgus about the knee, which is included in the algorithm. From our perspective, the DVJ protocols were very similar. It is important to appreciate that there is some amount of horizontal movement inherent in all DVJ tasks. It is not possible to perform a DVJ without some horizontal movement; without this, one would never leave the surface of the box. Consequently, the DVJ from which Myer and colleagues developed their clinical algorithm also included horizontal movement and was very similar to our DVJ protocol. In

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our study, we attempted to use a DVJ task that allowed functional movement during a clinic-based screening test but still had the capacity to be controlled over its application to thousands of participants. The protocol described by Padua et al[10] allowed us to meet that need. In our DVJ protocol, participants did not perform a "broad jump" off the top of the box, as suggested by Myer et al; instead, they were instructed to land in a standardized position that was located in front of the box in a manner very similar to that described by Myer et al.[3,7–9] We recognize that with increasing horizontal distance associated with the DVJ, there may be an increase in hip adduction and knee valgus motions.[11] Therefore, we would expect to see increased knee valgus in all participants during the DVJ task employed in our study.[11] Because all athletes completed the same movement task in our study, we would expect the resultant difference between our DVJ protocol and the DVJ protocol used by Myer et al to be similar across all athletes. Therefore, we fail to see how the ACL injury risk analysis would be affected. Myer et al also expressed concern that the movement task with increased horizontal movement resulted in increased initial contact valgus measurements[10] versus increased peak knee valgus load during the DVJ with less horizontal movement[5] and indicate that we should have evaluated "initial contact measures to help match the correct maneuver with the outcome of interest." We feel the DVJ as it was performed in our study is fundamentally identical to what was used by Myer et al in the development of their algorithm (both involve similar vertical and horizontal movements during execution of the DVJ). The algorithm utilizes a measure of knee valgus that is based on the position of the knee at initial contact and the position of the knee at maximum "valgus" (or medial knee position) and determines the resultant medial-directed knee movement, or valgus movement, that has occurred.[7–9] In this case, we followed the methods dictated by the algorithm, and therefore, we did match the correct maneuver with the outcome of interest (ACL injury).

Myer et al were concerned with the "lack of use of shoes for testing." They expressed concern that the absence of footwear in our study undermined the accuracy of the algorithm. A prior report has shown that ankle stiffness was different between barefoot and shod DVJs.[12] This same report, as well as others, have evaluated barefoot versus shod conditions during a terminal drop-landing task, without a jump, and shown conflicting results on the effect of barefoot versus shod landing on knee flexion, intersegmental moment, and energy absorption.[12,16] It is difficult to apply the results of these 2 conflicting studies to potential differences in knee flexion seen in our study. Therefore, we feel that the literature does not support the position that Myer et al have expressed in this case. The authors also recommend consistency regarding the use of shoes. The reason we did not use shoes in our study was, in fact, to be consistent across the testing of thousands of participants. We think that the study would have suffered more by having participants use different types of footwear (eg, sizes of cleats, sneakers, trainers, and barefoot-style footwear). Additional variability may have been introduced by having participants who wear a certain shoe (eg, cleats) be forced to use unfamiliar footwear (eg, a standardized shoe that they were not comfortable and familiar with). With these cases, there is no way to control the differences between footwear, and therefore, the most appropriate way to control this between-participant variable was to standardize this variable by requiring all participants to perform the task barefoot.

The authors also expressed concern regarding the amount of ankle separation that occurred when our participants performed the DVJ. Myer et al indicated that landing with ankle separation smaller than 35 cm can limit the potential valgus motion of the knee joint during the DVJ task and "is critical during assessment of medial knee motion utilized in the predictive algorithm. Without minimum foot/ankle separation, the medial knee motion is mechanically blocked by the contralateral limb, and the test is invalid." In response, we feel that it is important to point out that there was no indication in the papers published by Myer and colleagues that were associated with the development of the algorithm, or in the original DVJ methods paper,[3] that participants were instructed or attempted to land with their feet separated 35 cm apart. This is new information that was not made available before the start of our study. We have only been able to find information that states that the authors asked participants to stand on top of the box with their feet 35 cm apart prior to jumping.[3,5] In our study, we standardized the initial position of the participants, while they stood on the box with feet placed at shoulder width apart, and made no effort to control foot placement at landing. This produced foot placement while standing on the box that was very close to 35 cm. We allowed the participants to make the decision to place their feet where they felt most comfortable during the landing portion of the task. This is what occurs during participation in athletic events and activity when athletes are at risk for injury. We would also like to point out that if 35 cm is used for all participants, sometimes this distance is greater than shoulder width, and sometimes it is smaller and therefore is not necessarily the position at which the athlete would comfortably stand or jump during participation in athletic events. Having said all this, we were well aware of the concern that medial-directed knee motion would have been limited if the thighs/knees made contact during landing from the DVJ. We fully appreciate that this is a concern among those with large thigh mass. Medial-directed knee motion during the landing phase of the DVJ was not limited by contact between the participants' thighs/knees in our study, and consequently, the position of the participant's feet during the landing phase of the DVJ is not a concern.

The next concern involved the knee flexion range of motion measure that was established by soft tissue borders rather than joint centers, which was used by the Myer group. It was mentioned that "the authorship team also employed measurements of knee flexion angle that were not consistent with the prior reported methods." They went on to state that "the potential error for 2-dimensional digitization based on joint centers is known and methods validated." It is important for us to point out that identification of knee joint centers from 2- and 3-dimensional video data that are based on external landmarks attached to the surface of the lower extremity is highly variable and not accurate.[6,15] While we agree that there is potential for undocumented errors in the angle formed with the lower leg and thigh with this approach, this error is smaller than that created by approximating knee joint centers with the use of skin-based markers, which produce large amounts of artifact.[2,6,15] For example, a recent study by Li et al[6] revealed that the use of surface-based markers to measure knee flexion angle produced a mean root-meansquare difference of 9° in knee flexion in comparison with the known flexion angle between the femur and tibia. The maximum difference in knee flexion angle approached twice this value (15.8°). Our preliminary work determined that the most reproducible approach to measure knee flexion angle was to use the borders of the anterior aspects of the thigh and shank. The identification of joint centers and their subsequent use as landmarks to measure knee flexion angle only introduced additional variability.

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