# Challenges and Opportunities in Developing a Test Battery for Joint Mobility using Reach Tasks Starting from Upright Standing Positions

O. Eriksrud, P. Anderson, E. H. Andreassen, S. Litsos, F. O. Sæland, P. Federolf and J. Cabri
*Department of Physical Performance, Norwegian School of Sport Sciences, Oslo, Norway*

## 1 BACKGROUND

Joint mobility, the range of motion utilized to accomplish tasks, is fundamental to activities of daily living and athletic performance. Conventional tests of joint mobility are often performed joint-by-joint in supine or prone positions (Frost et al., 2013); (McGill et al., 2012). This approach to joint mobility testing has important conceptual shortcomings. For example, the kinetic chain is neglected and strength, balance or coordination issues, which could limit the effective range of motion in real-life situations, are not assessed. This might be one reason why many conventionally determined mobility variables often fail to predict performance (McGill et al., 2012).

Recently, there has been a development towards the use of tools and screens based on more global movement patterns (Cook et al., 2006a; 2006b); (Kiesel et al., 2007). Therefore, researchers are calling for a multifactorial approach in the assessment of human movement (Bahr and Krosshaug, 2005); (Federolf et al., in press). A systematic combination of different reach tests in an upright standing position, such as the Star Excursion Balance Test (SEBT) (Delahunt et al., 2013); (Plisky et al., 2006) may represent an approach to test joint mobility in a way that is more applicable in real-life situations.

## 2 OBJECTIVES

The purpose of this study was to determine if a systematic combination of upright standing reach tests may be used to develop a test battery for the assessment of joint mobility, and to identify the potential challenges that have to be addressed when applying these tests. In addition, it was assessed if selected conventional tests of mobility are correlated with performance in specific reach tests.

## 3 METHODS

Eight male subjects (23.1 ± 1.5 years; 183 ± 6 cm; 80.2 ± 9.3 kg) performed 20 different bilateral and unilateral hand reaches, 10 on each foot with toe touch of the opposite foot (see skeletal posture representations in Figure 1). The hand reaches were based on the angulations used in the SEBT. All tests started from an upright stance position with the subject then reaching in the following directions: anterior to the floor (A0); right anterolateral to the floor (R45); left anterolateral (L45); right lateral overhead (R90); left lateral overhead (L90); posterior overhead (P180); right posterolateral overhead (R135); left posterolateral overhead (L135); right rotation at shoulder height and (RRot); and left rotation at shoulder height (LRot).

Reach distances were determined with subjects standing on a custom testing mat featuring a mesh of 4 crossing lines in anterior-posterior, right-left, and diagonal directions intercepted by concentric circles at 10-centimeter intervals (centre graph in Figure 1). This allowed for an accurate measurement of all reach distances. Reaches were obtained in centimetres with the exception of RRot and LRot, which were measured in degrees. All reaches were performed with three repetitions and all subjects executed the reach tests in the same order. Anthropometric measures of height, leg length, arm length wingspan and weight were also obtained.

Full body three-dimensional kinematic data were obtained at 480 Hz using 79 reflective markers recorded with 14 Oqus cameras (Qualisys AB, Gothenburg, Sweden). Joint angles of ankles, knees, hips, trunk, neck, shoulders, elbows and wrists were calculated at maximum reach distance or angle using Visual 3D (C-Motion, Germantown, USA).

Subsequent to the reach tasks, a series of conventional mobility tests were conducted on a clinical assessment table with the subjects in a prone or a seated position. These tests included Thomas test (i.e. supine test of hip extension), ankle dorsiflexion, and hip internal and external rotation.

Eriksrud O., Anderson P., H. Andreassen E., Litsos S., O. Sæland F., Federolf P. and Cabri J..
Challenges and Opportunities in Developing a Test Battery for Joint Mobility using Reach Tasks Starting from Upright Standing Positions.

A goniometer was used to determine joint ranges of motion.

Pearson product moment correlations between joints angles and reach performance were calculated. Correlations were considered significant at $p < 0.05$ and a statistical trend was assumed for $p < 0.1$.

# 4 RESULTS

In all reach tests significant correlations were found between the reach distance and a specific set of joint angles. Figures 1 and 2 give a graphical representation of the results obtained for the tests carried out when standing on the left leg. Analogue results were obtained for the right leg. However, not in all cases a-priory expected correlations between reach performance and joint angles were confirmed by the experimental results.

All reach performances were significantly correlated with all anthropometric measures, height, leg length, arm length, wingspan, with the exception of body weight for which no significant correlation was found with any of the reach tests. Joint range of motion as determined in the conventional tests correlated with reach performance only in 7 of 22 analysed comparisons.

# 5 DISCUSSION

The results of the current study suggest that the performance in each of the reach tests depends on the subjects' ability to engage a specific combination of joint angles. Therefore a suitable combination of reach tasks might, in turn, be able to reveal deficits in an individual's effective, task- oriented mobility.

Many of the postures observed in the resultant configurations (Figures 1 and 2) suggest that the optimal combination of joint angles may not be limited by mobility in specific joints. Instead, it appears to depend on the subjects' ability to stabilize their posture and to counterbalance their weight. This consideration may be one of the reasons for the poor correlation observed between joint range of motion determined in conventional mobility tests and performance variables, e.g. upright standing reach (current study) or game performance variables



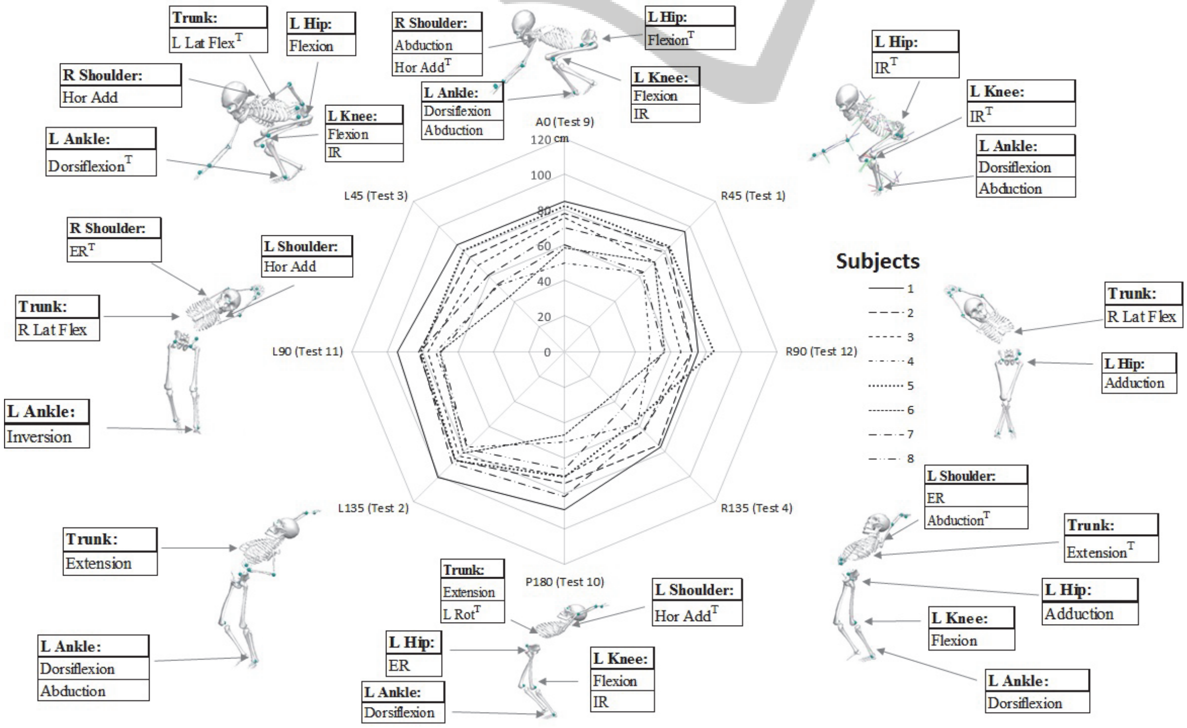


Figure 1: Illustration of the tests performed on the left foot. The centre diagram shows the average maximum reach distance for each subject and the skeletons visualize the subjects' postures in each reaching task. The joint angles that correlated significantly with the reach distance or that showed a statistical trend were explicitly pointed out for each test ($^T$=statistical trend). The following abbreviations were used: L=left, R=right, ER=external rotation, IR=internal rotation, L Lat Flex=left lateral flexion, R Lat Flex=right lateral flexion, Hor Abd=horizontal abduction, Hor Add=horizontal adduction.

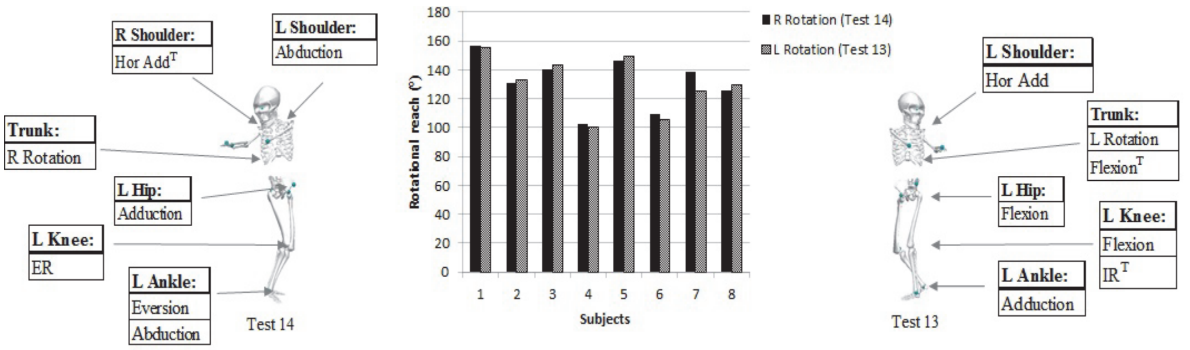


Figure 2: Illustration of the rotational tests performed on the left foot. The centre diagram shows the maximum reach scores of the eight subjects, the figures to the right and left show the postural setup and point out joint angles that correlated with the reach performance ($^{T}$=statistical trend). L=left, R=right, IR=internal rotation, ER=external rotation, Hor Add=horizontal adduction.

(McGill et al., 2012). Tests for joint mobility based on "real-life" tasks such as reach tests should therefore consider balance and joint stability in their assessment.

Furthermore, reach distance correlated with anthropometric variables indicating that normalization or scaling of the anthropometric properties is important for comparison between subjects. In addition, joint mobility achieved during the reach tests has to be analysed relative to established reference values for joint mobility.

In conclusion, reach tests starting from upright standing positions challenge joint mobility in a more natural and specific way compared to conventional mobility tests and appears to be more relevant to activities of daily living and athletic performance. It may be worth to further investigate this approach, however, several additional issues such as joint stability, counterbalancing of body weight, and scaling will also have to be addressed.

## ACKNOWLEDGEMENTS

The contribution of Ghelem, A. and Parnevik-Muth, J. in developing the reach test battery was instrumental and is thankfully acknowledged.

## REFERENCES

Bahr, R., & Krosshaug, T. (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. *British Journal of Sports Medicine, 39*(6), 324-329.

Cook, G., Burton, L., & Hoogenboom, B. (2006a). Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. *North American Journal of Sports Physical Therapy, 1*(2), 62-72.

Cook, G., Burton, L., & Hoogenboom, B. (2006b). Pre-participation screening: the use of fundamental movements as an assessment of function - part 2. *North American Journal of Sports Physical Therapy, 1*(3), 132-139.

Delahunt, E., Chawke, M., Kelleher, J., Murphy, K., Prendiville, A., Sweeny, L., et al. (2013). Lower limb kinematics and dynamic postural stability in anterior cruciate ligament-reconstructed female athletes. *Journal of Athletic Training, 48*(2), 172-185.

Federolf, P., Reid, R., Gilgien, M., Haugen, P., Smith, G. (in press). The application of principal component analysis to quantify technique in sports. *Scandinavian Journal of Medicine & Science in Sports*. doi: 10.1111/j.1600-0838.2012.01455.x.

Frost, D., Andersen, J., Lam, T., Finlay, T., Darby, K., & McGill, S. (2013). The relationship between general measures of fitness, passive range of motion and whole-body movement quality. *Ergonomics, 56*(4), 637-649.

Kiesel, K., Plisky, P. J., & Voight, M. L. (2007). Can Serious Injury in Professional Football be Predicted by a Preseason Functional Movement Screen? *North American Journal of Sports Physical Therapy, 2*(3), 147-158.

McGill, S. M., Andersen, J. T., & Horne, A. D. (2012). Predicting performance and injury resilience from movement quality and fitness scores in a basketball team over 2 years. *Journal of Strength and Conditioning Research, 26*(7), 1731-1739.

Plisky, P. J., Rauh, M. J., Kaminski, T. W., & Underwood, F. B. (2006). Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *The Journal of Orthopaedic and Sports Physical Therapy, 36*(12), 911-919.