MOVEMENT SCREENING TOOL IDENTIFYING ATHLETES AT RISK OF DEVELOPING PATELLAR TENDINOPATHY

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The purpose of this study was to develop a movement screening tool to predict the presense of patellar tendon abnormality (PTA) in asymptomatic athletes who are at an increased risk of developing patellar tendinopathy (PT). Ten asymptomatic junior pre-elite basketball athletes with a PTA were matched with ten athletes with normal patellar tendons. Participant's landing technique during stop-jump movement, lower limb flexibility, adiposity, and vertical jump performance were measured. An easily implemented screening tool comprising of the criteria of hip range of motion and knee angle at initial foot-force platform contact during landing, and quadriceps flexibility, can now be measured in athletes to enable coaches and/or clinicians to predict for the presence of a PTA, and in turn, identify athletes at higher risk of developing PT.

KEY WORDS: Knee injury, biomechanics, movement screening, risk factors, prevention through prediction.

INTRODUCTION: Overuse injuries such as patellar tendinopathy (PT) have increased (Lian, Engebretsen, & Bahr, 2005), with a prevalence range from 10% in college athletes (Witvrouw, Bellemans, Lysens, Danneels, & Cambier, 2001) to 32% in elite basketball athletes (Lian, et al., 2005). The presence of a PTA is used to confirm diagnosis of PT (Cook, Malliaras, De Luca, Ptasznik, & Morris, 2005; Malliaras, Cook, & Kent, 2006), and in asymptomatic athletes it is also identified as a risk factor, increasing the likelihood of an athlete developing PT (Cook, Khan, Kiss, Purdam, & Griffiths, 2000; Cook, Khan, Kiss, Coleman, & Griffiths, 2001). By identifying readably modifiable risk factors influential in predicting the presence of a PTA in asymptomatic athletes, may provide a tool to assisting in implementing risk modification strategies such as landing retraining can be implemented to reduce further progression of the PTA into PT.

Altered landing strategies have been identified in asymptomatic athletes with a PTA (Edwards, Steele, McGhee, Beattie, Purdam, & Cook, 2010) and athletes with current symptoms of PT (Richards, Ajemian, Wiley, & Zernicke, 1996; Bisseling, Hof, Bredeweg, Zwerver, & Mulder, 2007, 2008) and are thought to increase their risk of developing PT. Other risk factors associated with PT that are also readily measurable and modifiable that may be included with a movement screening tool include increased adiposity (Crossley et al., 2007) decreased lower limb flexibility (Witvrouw, Bellemans, Danneels, & Cambier, 2001), and higher vertical jump height (Lian, Refsnes, Engebretsen, & Bahr, 2003). If any of these modifiable risk factors are meaningful predictors of an increased risk of developing a PTA and in turn PT, these influential risk factors can be used to screen athletes to enable the implementation of risk modifications strategies to reduce injury risk and prevalence of PT with the sporting community. Therefore, the purpose of this study was to determine the risk factors that are most influential in predicting the incidence of PTA and to develop an easily implemented movement screening tool based on critical risk factors associated with PT that can be utilised by coaches and/or clinicians to identify their athletes who are at higher risk of developing PT. We hypothesis that a criteria of altered hip and knee motion strategies during a stop-jump task, lower limb flexibility, increased adiposity, and increased vertical jump performance will allow a *"Prevention through Prediction"* approach to determined the presence of a PTA in asymptomatic individuals.

METHODS: Of the twenty-two junior pre-elite basketball participants recruited, ten participants with a PTA with no current signs of PT were individually matched for height, mass, and test lower limb to ten participants with normal patellar tendons. If a participant had bilateral PTA, the lower limb with the larger PTA area (mm^2) (Edwards, et al., 2010) was selected for analysis. Each participants' patellar tendon morphology, Victorian Institute of Sport Assessment score, body composition, lower limb flexibility and maximum vertical jump height were measured prior to performing five successful stop-jump movements. The stop-jump task involved five phases including a horizontal preparation, horizontal landing, horizontal take-off, vertical preparation and vertical landing phase (Edwards, Steele, Cook, Purdam, & McGhee, 2012). A successful stop-jump was defined as a participant obtaining an adequate approach speed of between 4.5 and 5.5 $m{\cdot}s^{-1}$ during the horizontal preparation phase, placing a foot wholly on the force platform during the horizontal landing phase, and contacting ball suspended from the ceiling with both hands. During each trial, the ground reaction forces generated at landing were recorded (2400 Hz) using a multichannel force platform with built-in charge amplifier (Kistler, Winterthur, Switzerland) embedded in the floor and connected to a control unit (Kistler, Winterthur, Switzerland), and the participant's three-dimensional lower limb and trunk motion was recorded (240 Hz) using a Qualisys Oqus 300 camera system (Qualisys AB, Göteborg, Sweden). Passive reflective markers were placed on each participant's lower limbs, pelvis and torso.

Data Analysis: Analyses of the kinematic and kinetic data were performed using Visual 3D software (Version 3, C-Motion, Maryland, USA). The raw kinematic coordinates, ground reaction forces, free moments and centre of pressure data were initially filtered using a fourth-order zero-phase-shift Butterworth digital low pass filter (f_c=18 Hz) before calculating individual ground reaction forces and joint kinematics. Multiple regression (forward method) analysis was used to determine significant factors in estimating PTA presence (dependent variable) where the alpha was set at P <0.05. All independent variables were continuous and included seven different variables during the landing phase (knee and hip joint angle, and trunk segment angle at IC and at the time of the $Knee_{Max}$, and hip joint angle range of motion (hip joint angle at $Knee_{max}$ minus hip joint angle at IC)) and five other variables (dorsiflexion, hamstring and quadriceps flexibility, maximum vertical jump height, and adiposity). Statistically significant independent variables identified as predictors of PTA presence (0=no evidence of PTA, 1=evidence of any degree of PTA) from the regression analysis was included in a separate discriminate analysis to correctly classify PTA presence using a leave-one-out classification.

RESULTS: Results of the measured variables included in the multiple regression are outlined in Table 1. Linear regression model (see equation 1) indicated that the significant predictors of PTA presence (Equation 1) were hip joint ROM (r^2=0.474) and knee flexion at initial foot-force platform contact (r^2=0.112) during stop-jump task, and quadriceps flexibility (r^2=0.090). Discriminate analysis indicated that the respective significant predictors of PTA presence were able to classify the presence of PTA with 95% accuracy and 95% cross-validation.

Equation 1: Presence of PTA in asymptomatic athletes

$$\gamma' = 0.965 + (0.024 \times hip\ ROM) + (0.013 \times quadriceps\ flexibility) + (0.024 \times knee\ flexion\ at\ IC)$$

DISCUSSION: In planning and implementing movement screening assessment tools, it is critical that the influence of injury specific risk factors associated with the developing of PT be identified to enable appropriate modification strategies to be developed and implemented to reduce the risk of PT. The results of this study support our hypothesis with the identification of significant variables that enable the prediction of PTA presence in pre-elite athletes. Implementation of this study's movement screening tool will enable *"Prevention through Prediction"* approach to reduce the risk of PT in athletes.

Primary influential risk factor that predicted the presence of PTA in asymptomatic was hip joint ROM during stop-jump landing. This reinforces the importance of lumbopelvic control within rehabilitation programs for PT with previous research identifying asymptomatic athletes with a PTA utilise an different movement strategy (Edwards, et al., 2010). That is, PTA participants extended their hips rather than the CONTROL participants who flexed their hip during landing. Another significant predictor of the presence of a PTA in an asymptomatic participants was greater knee flexion at IC during stop-jump landing compared to athletes with normal patellar tendons. As histological adaptations occur as a result of increased patellar tendon tension and compressive loads (Hamilton & Purdam, 2004), this current study provides further evidence that the direction of the load that the patellar tendon sustains is more critical than the magnitude of this load in the development of a PTA (Edwards, et al., 2010). Lastly, reduced quadriceps flexibility was the only other significant predictor of the presence of a PTA in asymptomatic athletes, which supports previous research that has associated this variable as a risk factor in the development of PT (Witvrouw, et al., 2001; Cook, Kiss, Khan, Purdam, & Webster, 2004). Identification of hip joint ROM and knee joint angle at IC during stop-jump landing, and quadriceps flexibility as significant predictors of the presence of a PTA, allows these variables to be implemented as a movement screening criteria to predict asymptomatic athletes at risk of developing a PTA. Discriminate analysis using these three variables correctly classes all participants with the presence of a PTA with only one false-positive of a participant with normal patellar tendons.

Table 1: Means (±SD) of independent and dependent variables included in multiple regression analysis to predict PTA presence and severity.

Variable	Normal Tendon	PTA
PTA Measurement (mm^2)		
PTA area		24.0 ± 20
3D Joint Angles (°)		
Knee flexion at IC	26.5 ± 5.6	34.3 ± 8.4
Hip flexion at IC	45.0 ± 9.7	54.1 ± 9.8
Trunk flexion at IC	-10.8 ± 7.9	-8.7 ± 7.0
Knee flexion at $Knee_{Max}$	75.3 ± 10.6	76.1 ± 8.0
Hip flexion at $Knee_{Max}$	51.0 ± 9.7	46.5 ± 6.1
Trunk flexion at $Knee_{Max}$	-5.6 ± 9.1	3.4 ± 6.8
Hip flexion ROM	-6.1 ± 8.0	7.6 ± 6.3
2D Joint Angles (°)		
Knee flexion at IC	29.8 ± 6.5	34.8 ± 9.3
Hip flexion at IC	46.8 ± 11.1	56.8 ± 10.5
Trunk flexion at IC	9.7 ± 9.2	2.8 ± 9.1
Knee flexion at $Knee_{Max}$	81.7 ± 5.7	73.1 ± 11.3
Hip flexion at $Knee_{Max}$	46.3 ± 10.7	41.0 ± 7.9
Trunk flexion at $Knee_{Max}$	18.7 ± 12.2	12.1 ± 6.7
Hip flexion ROM	0.4 ± 7.1	17.3 ± 7.5
Other Risk Factors		
VISA	95.3 ± 4.9	90.8 ± 13.3
BF (%)	11.7 ± 4.6	13.3 ± 5.4
BF(g)	9042 ± 5100	11340 ± 5782
Vertical Jump (cm)	51.5 ± 6.4	54.7 ± 7.8
Static Dorsiflexion (cm)	11.5 ± 3.6	10.3 ± 1.6
Static Hamstring Flexibility (°)	101.3 ± 8.5	91.3 ± 27.2
Static Quadriceps Flexibility (°)	47.4 ± 6.6	63.3 ± 19.0

Initial foot-ground contact (IC), maximum knee joint flexion angle ($Knee_{Max}$), range of motion (ROM), Victorian Institute of Sport Assessment (VISA), body fat (BF).
For the above rotations: knee flexion, hip flexion and trunk flexion are all positive.

CONCLUSION: An easily implemented movement screening tool comprising of measuring three criteria enables coaches and/or clinicians to predict for the presence of a PTA, and in turn, identify athletes at higher risk of developing PT. Utilising a *"Prevention through Prediction"* approach will allow risk factor modification strategies to be developed and implemented at a community sporting level based on these movement screening tool criteria to reduce the risk of developing PT.

REFERENCES:

Bisseling, R. W., Hof, A. L., Bredeweg, S. W., Zwerver, J., & Mulder, T. (2007). Relationship between landing strategy and patellar tendinopathy in volleyball. *British Journal of Sports Medicine,* 41(7), e8.

Bisseling, R. W., Hof, A. L., Bredeweg, S. W., Zwerver, J., & Mulder, T. (2008). Are the take-off and landing phase dynamics of the volleyball spike jump related to patellar tendinopathy? *British Journal of Sports Medicine,* 42(6), 483.

Cook, J. L., Khan, K. M., Kiss, Z. S., Coleman, B. D., & Griffiths, L. (2001). Asymptomatic hypoechoic regions on patellar tendon ultrasound: A 4-yr clinical and ultrasound followup of 46 tendons. *Scandinavian Journal of Medicine & Science in Sports,* 11(6), 321-327.
Cook, J. L., Khan, K. M., Kiss, Z. S., Purdam, C. R., & Griffiths, L. (2000). Prospective imaging study of asymptomatic patellar tendinopathy in elite junior basketball players. *Journal of Ultrasound in Medicine,* 19(7), 473-479.
Cook, J. L., Kiss, Z. S., Khan, K. M., Purdam, C. R., & Webster, K. E. (2004). Anthropometry, physical performance, and ultrasound patellar tendon abnormality in elite junior basketball players: a cross-sectional study. *British Journal of Sports Medicine,* 38(2), 206-209.
Cook, J. L., Malliaras, P., De Luca, J., Ptasznik, R., & Morris, M. (2005). Vascularity and pain in the patellar tendon of adult jumping athletes: a 5 month longitudinal study. *British Journal of Sports Medicine,* 39(7), 458.
Crossley, K. M., Thancanamootoo, K., Metcalf, B. R., Cook, J. L., Purdam, C. R., & Warden, S. J. (2007). Clinical features of patellar tendinopathy and their implications for rehabilitation. *Journal of Orthopaedic Research,* 25(9), 1164-1175.
Edwards, S., Steele, J. R., Cook, J. L., Purdam, C. R., & McGhee, D. E. (2012). Lower Limb Movement Symmetry Cannot Be Assumed When Investigating the Stop-Jump Landing. *Medicine & Science in Sports & Exercise, Publish Ahead of Print*. doi: 10.1249/MSS.0b013e31824299c3
Edwards, S., Steele, J. R., McGhee, D. E., Beattie, S., Purdam, C., & Cook, J. L. (2010). Landing Strategies of Athletes with an Asymptomatic Patellar Tendon Abnormality. *Medicine & Science in Sports & Exercise,* 42(11), 2072.
Hamilton, B., & Purdam, C. (2004). Patellar tendinosis as an adaptive process: A new hypothesis. *British Journal of Sports Medicine,* 38(6), 758-761.
Lian, Ø., Engebretsen, L., & Bahr, R. (2005). Prevalence of Jumper's Knee Among Elite Athletes From Different Sports. *American Journal of Sports Medicine,* 33(4), 561-567.
Lian, Ø., Refsnes, P. E., Engebretsen, L., & Bahr, R. (2003). Performance characteristics of volleyball players with patellar tendinopathy. *American Journal of Sports Medicine, 31*(3), 408.
Malliaras, P., Cook, J. L., & Kent, P. (2006). Reduced ankle dorsiflexion range may increase the risk of patellar tendon injury among volleyball players. *Journal of Science and Medicine in Sport,* 9(4), 304-309.
Richards, D. P., Ajemian, S. V., Wiley, J. P., & Zernicke, R. F. (1996). Knee joint dynamics predict patellar tendinitis in elite volleyball players. *American Journal of Sports Medicine,* 24(5), 676.
Witvrouw, E., Bellemans, J., Lysens, R., Danneels, L., & Cambier, D. (2001). Intrinsic risk factors for the development of patellar tendinitis in an athletic population. *American Journal of Sports Medicine,* 29(2), 190.

Acknowledgement: The authors would like to gratefully acknowledge Michael Jones and PRP Diagnostic Imaging for the funding of the ultrasounds in this study. There are no conflicts of interest from any of the authors.