

1-1-2013

## A lower limb assessment tool for athletes at risk of developing patellar tendinopathy

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### Recommended Citation

Mann, K., Edwards, S., Drinkwater, E. J., & Bird, S. (2013). A lower limb assessment tool for athletes at risk of developing patellar tendinopathy. DOI: <https://doi.org/10.1249/MSS.0b013e318275e0f2>

[10.1249/MSS.0b013e318275e0f2](https://doi.org/10.1249/MSS.0b013e318275e0f2)

This is an Author's Accepted Manuscript of: Mann, K., Edwards, S., Drinkwater, E. J., & Bird, S. (2013). A lower limb assessment tool for athletes at risk of developing patellar tendinopathy. *Medicine and Science in Sports and Exercise*, 45(3), 527-533. Available [here](#)

This Journal Article is posted at Research Online.

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1 MANUSCRIPT – MEDICINE AND SCIENCE IN SPORT AND EXERCISE

2 **A lower limb assessment tool for athletes at risk of developing patellar tendinopathy**

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16  
17 Running Title: Patellar tendinopathy movement screening tool

18  
19 **Disclosure statement:** The authors acknowledge PRP Diagnostic Imaging for the funding of the  
20 ultrasounds in this study, and that there is no conflict of interest for any of the authors.

21

1 **ABSTRACT**

2 **Purpose:** Patellar tendon abnormality (PTA) on diagnostic imaging is part of the diagnostic criteria for  
3 patellar tendinopathy. A PTA in addition to altered landing strategies are primary risk factors that  
4 increase the likelihood of asymptomatic athletes developing patellar tendinopathy. Therefore, the aim  
5 of this study was to examine risk factors that are predictors of the presence and severity of a PTA in  
6 junior pre-elite athletes.

7 **Methods:** Ten junior pre-elite male basketball athletes with a PTA were matched with ten athletes  
8 with normal patellar tendons. Participants had patellar tendon morphology, Victorian Institute of Sport  
9 Assessment score (VISA), body composition, lower limb flexibility and maximum vertical jump height  
10 measured prior to performing five successful stop-jump tasks. During each landing trial, both two-  
11 and three-dimensional kinematics and ground reaction forces were recorded. Multiple regression  
12 analyses were used to identify factors for estimating PTA presence and severity, and discriminate  
13 analysis used to classify PTA presence.

14 **Results:** Sixty-eight percent of variance for presence of a PTA was accounted for by hip joint range of  
15 motion (ROM), knee joint angle at initial foot-ground contact (IC) during stop-jump and quadriceps  
16 flexibility, whereas hip joint ROM and VISA accounted for 62% of variance for PTA severity.  
17 Prediction of the presence of a PTA was achieved with 95% accuracy and 95% cross-validation.

18 **Conclusions:** An easily implemented, reliable and valid movement screening tool comprising of three  
19 criteria's enables coaches and/or clinicians to predict for the presence and severity of a PTA in  
20 asymptomatic athletes. This enables identification of asymptomatic athletes at higher risk of  
21 developing patellar tendinopathy, which allows the development of effective preventative measures to  
22 aid in the reduction of patellar tendinopathy injury prevalence.

23 **Keywords:** Knee injury, biomechanics, movement screening, prevention through prediction, landing  
24

## 1 INTRODUCTION

2 **Paragraph Number 1.** Identified in repetitive jumping sports, overuse injuries such as patellar  
3 tendinopathy have increased (23), with a prevalence range from 10% in college athletes (39) to 32%  
4 in elite basketball athletes (23). Although the overall prevalence across different sports indicates that  
5 every fifth elite athlete will suffer patellar tendinopathy within their career, it is particularly concerning  
6 that in basketball 55% of elite basketball players have reported current or previous patellar  
7 tendinopathy symptoms (23). Classified as a degenerating overuse knee injury (33), patellar  
8 tendinopathy is diagnosed using a combination of a history of activity related pain (25), tenderness on  
9 palpation (26), Victorian Institute of Sport Assessment (VISA) score of less than 80 (38), and patellar  
10 tendon abnormality (PTA) on diagnostic imaging (9). As PTA's tend to emerge during the  
11 developmental adolescent years (9), it is imperative that risk factors associated with patellar  
12 tendinopathy within the pre-elite population be identified and understood in order to develop effective  
13 preventative measures to aid in the reduction of patellar tendinopathy injury rates (36). Prevention  
14 through prediction aims to reduce injury rates by predicting athletes at risk of developing patellar  
15 tendinopathy within the sporting population and implementing risk modification strategies to reduce  
16 the patellar tendinopathy incidence rate.

17 **Paragraph Number 2.** With controversy surrounding the precise etiology of PT, a combination of  
18 internal and external risk factors is thought to play a part in the development of patellar tendinopathy  
19 (10, 33). Although the presence of a PTA is used to confirm diagnosis of patellar tendinopathy (9,  
20 26), PTA's have also been identified as a risk factor in the development of patellar tendinopathy (8).  
21 Asymptomatic athletes with a PTA have an increased likelihood of developing patellar tendinopathy  
22 (7, 8), especially males who are twice as likely to develop a PTA compared to females (9).  
23 Regardless of this supporting evidence of PTA as a risk factor for patellar tendinopathy development,  
24 the clinical importance of PTA changes have not yet been identified as the size of the PTA varies over  
25 time and is unable to predict patellar tendinopathy symptoms (18). Nevertheless, identification of  
26 asymptomatic athletes with a PTA utilising a different landing strategy may provide a method to  
27 identify these athletes at risk of developing patellar tendinopathy.

28 **Paragraph Number 3.** With repetitive landing being identified as the primary risk factor of patellar  
29 tendinopathy (10, 33), symptomatic athletes with patellar tendinopathy (4, 34) and asymptomatic  
30 athletes with a PTA (13) have been associated with altered landing strategies. The critical

1 characteristics associated with these altered landing strategies are knee and hip joint motion. During  
2 a dynamic landing, maximum knee joint flexion is the strongest predictor of symptomatic patellar  
3 tendinopathy (34), and asymptomatic athletes with PTA compared to athletes with normal patellar  
4 tendons displayed increased knee joint flexion at initial foot-ground contact (IC) and different hip  
5 movement strategies, whereby they extend their hip during landing as opposed to flexing their hips  
6 (13).

7 **Paragraph Number 4.** As these altered landing strategies primarily occur in the sagittal plane, it may  
8 be possible to identify athletes with these altered landing patterns utilizing a simple two-dimensional  
9 video camera as opposed to three-dimensional motion analysis. Although three-dimensional lower  
10 limb motion analysis is considered the gold standard of assessing landing technique, it is costly, and  
11 extensively time and space consuming (29). It is therefore not practical for all coaches and/or  
12 clinicians to utilize this method. A successful alternative method for validly screening athletes at risk  
13 in a cost, time and space effective method is to screen athletes using a two-dimensional video  
14 analysis, previously used in knee joint injuries (31). Nevertheless, the two-dimensional video analysis  
15 may be limited if there is a lack of validity between three- and two-dimensional measures (29).  
16 Therefore, further research is warranted to determine if this analysis method could be implemented to  
17 developing a movement screening tool for another knee joint injury, patellar tendinopathy.

18 **Paragraph Number 5.** Other risk factors associated with patellar tendinopathy that are also readily  
19 measurable and modifiable that may be included with a movement screening tool to assess injury risk  
20 include increased adiposity (10, 17), decreased lower limb flexibility (26, 39), and higher vertical jump  
21 height (25). If any of these modifiable risk factors are meaningful predictors of an increased risk of  
22 developing a PTA and therefore patellar tendinopathy, these risk factors should be used to screen  
23 athletes. Athletes identified as being at risk can then have modification strategies implemented to  
24 reduce injury risk and/or prevalence of patellar tendinopathy.

25 **Paragraph Number 6.** The present study aimed to i) determine the risk factors that are most  
26 influential in predicting the incidence and severity of PTA and ii) to develop an easily implemented,  
27 valid and reliable movement screening tool based on critical risk factors associated with patellar  
28 tendinopathy that can be utilized by coaches and/or clinicians to identify their athletes who are at  
29 higher risk of developing patellar tendinopathy. We hypothesised that a criteria of altered hip and  
30 knee motion strategies during a stop-jump task, lower limb flexibility, increased adiposity, and

1 increased vertical jump performance will allow a prevention through prediction approach to determine  
2 the i) presence; and ii) severity of a PTA in asymptomatic individuals.

### 3 **METHODS**

#### 4 ***Participants***

5 **Paragraph Number 7.** Twenty-two junior pre-elite male basketball athletes (mean age =  $17.7 \pm 1.5$   
6 years, height =  $183 \pm 10$  cm; mass =  $78.0 \pm 14.7$  kg) were recruited from junior pre-elite rural  
7 representative teams. The presence of a PTA (Table 1) (7) was assessed by an experienced  
8 musculoskeletal sonographer (M.J., PRP Imaging Bathurst NSW Australia) using a 12MHz linear  
9 array ultrasound transducer (Toshiba, Aplio XG, Japan). Body composition was estimated by a dual-  
10 energy X-ray absorptiometry (DEXA; XR800, Norland, Cooper Surgical Company, USA) using a  
11 supine whole body scan performed by a qualified technician (scanning resolution =  $6.5 \times 13.0$  mm;  
12 scanning speed =  $130 \text{ mm s}^{-1}$ ). Each participant's height, body composition, anthropometric  
13 dimensions, static dorsiflexion (26), static hamstring (39) and quadriceps flexibility (14), and maximum  
14 vertical jump height (25, 36) were measured before determining their dominant lower limb on the  
15 basis of their preferred kicking leg (15). Ten participants with PTA with no current signs of patellar  
16 tendinopathy were individually matched for height, mass, and test limb to ten participants with normal  
17 patellar tendons (13). The lower limb with the larger PTA area ( $\text{mm}^2$ ) (24) was selected for analysis if  
18 a participant had bilateral PTA. Written informed consent was obtained from each participant prior to  
19 data collection, with parental/guardian consent obtained for minors. All methods were approved by the  
20 institution's Human Research Ethics Committee (2011/071).

21 < Insert Table 1 about here >

#### 22 ***Experimental Task***

23 **Paragraph Number 8.** Since a substantial component of basketball play is rapid acceleration,  
24 deceleration (28), and repetitive landing (27), the stop-jump task was chosen as the experimental  
25 task. The stop-jump task involved five phases, which included a horizontal preparation, horizontal  
26 landing, horizontal take-off, vertical preparation and vertical landing phase (12). Each participant was  
27 required to perform the horizontal preparation phase accelerating forwards for 10 m towards a force  
28 platform (mean approach speed =  $5.1 \pm 0.3 \text{ m}\cdot\text{s}^{-1}$ ), which was measured using infrared timing lights

1 (Speed Light, Swift Sports Equipment, Lismore, Australia). Then each participant performed the  
2 horizontal landing phase by jumping off one lower limb then stopping abruptly using a simultaneous  
3 two-foot landing with one foot wholly contacting a force platform, and then immediately jump vertically  
4 upwards (horizontal takeoff phase) off the ground to strike a ball suspended from the ceiling (vertical  
5 preparation phase), with both hands (vertical jump height =  $52 \pm 7$  cm). Finally, participants  
6 performed the vertical landing phase by landing on both feet a second time (vertical landing phase).  
7 Participants performed five successful stop-jump movements for each lower limb. A successful stop-  
8 jump was defined as a participant obtaining an adequate approach speed of between 4.5 and 5.5  
9  $\text{m}\cdot\text{s}^{-1}$  during the horizontal preparation phase, placing a foot wholly on the force platform during the  
10 horizontal landing phase, and contacting ball suspended from the ceiling with both hands. The  
11 approach speed was based on the 10 m sprint time (3) and average sprint duration of 2.1 s (1) as  
12 these are typical values in junior elite male basketball. During task familiarisation, jump height effort  
13 was standardised among the participants by positioning the ball at the maximum height each  
14 participant could touch the ball with both hands after performing the horizontal landing phase of the  
15 stop-jump task.

## 16 ***Experimental Procedure***

17 ***Paragraph Number 9.*** Prior to completing a 5- to 10-min warm-up on a cycle ergometer (Monark  
18 828E, Varburg, Sweden), a static trial was performed. Each participant was then familiarised with the  
19 stop-jump task before performing at least five successful stop-jump trials. During each trial, the  
20 ground reaction forces generated at landing were recorded (2400 Hz) using a multichannel force  
21 platform with built-in charge amplifier (Type 9281CA, Kistler, Winterthur, Switzerland) embedded in  
22 the floor and connected to a control unit (Type 5233A, Kistler, Winterthur, Switzerland). The  
23 participant's three-dimensional lower limb and trunk motion was recorded (240 Hz) using a Qualisys  
24 Oqus 300 camera system (Qualisys AB, Göteborg, Sweden) and two-dimensional lower limb and  
25 trunk motion was recorded (30 Hz) using a digital video camera (GZ-MG465, JVC, Yokohama,  
26 Japan). Passive reflective markers were placed on each participant's lower limbs, pelvis and torso,  
27 on the shoe at the first and fifth metatarsal head, mid anterior foot and calcaneous, lateral and medial  
28 malleolus, lateral and medial femoral epicondyle, four-marker cluster placed on the leg and thigh,  
29 greater trochanter, anterior superior iliac spine, posterior superior iliac spine, iliac crest, sternal notch,  
30 xiphoid process, acromion, lumbo-sacral (L5-S1) intervertebral joint space, thoraco-lumbar (T12-L1)

1 intervertebral joint space, bilaterally on the ribcage at the level of the T12-L1 intervertebral joint space  
2 and immediately superior to the iliac crest marker, and five tracking markers placed on the lumbar  
3 region. To avoid losing view of the passive reflective markers, the participant's wore minimal clothing  
4 (shorts), and their own socks and athletic running shoes.

## 5 ***Data Reduction and Analysis***

6 ***Paragraph Number 10.*** Analysis of the three-dimensional kinematic and kinetic data was performed  
7 using Visual 3D software (Version 4, C-Motion, Germantown, MD). The raw kinematic coordinates,  
8 ground reaction forces, free moments and centre of pressure data were initially filtered using a fourth-  
9 order zero-phase-shift Butterworth digital low pass filter ( $f_c = 18$  Hz) before calculating individual  
10 ground reaction forces and joint kinematics. Segment masses were defined from Zatsiorsky et al.  
11 (40) for the foot, shank and thigh segments, and Pearsall et al. (32) for the pelvis, lumbar, thorax and  
12 trunk segments. Segmental inertial properties of each segment were modelled using geometric  
13 primitives (20), with the foot, shank and thigh defined as a frusta of a right cone (16), and the pelvis,  
14 lumbar, thorax and trunk defined as elliptical cylinders (35). With respect to the Cardanic axes of the  
15 local joint coordinate system, intersegmental joint angles were expressed for knee and hip joint  
16 angles as flexion-extension, adduction-abduction and internal-external rotation, and trunk angles as  
17 extension-flexion, right-left lateral flexion, and left-right rotation. Using the 18 Hz filtered kinetic data,  
18 the landing phase was defined from IC when the vertical ground reaction force exceeded 10 N to the  
19 first local minimum, to peak knee joint flexion angle ( $Knee_{max}$ ). For each trial, the maximum vertical  
20 jump height (11), knee and hip joints and trunk segment kinematics at IC and at the time of the  
21  $Knee_{Max}$  were calculated.

22 ***Paragraph Number 11.*** The two-dimensional video data of the lower limb and trunk motion was  
23 analysed using Silicon Coach Pro (Version 6; Silicon Coach Ltd., Dunedin, New Zealand) software.  
24 Based on the passive reflective markers, knee and hip joint, and trunk segment angles were  
25 calculated in the sagittal plane at IC and at the time of the  $Knee_{Max}$ . The DEXA scan was analysed  
26 (IlluminatusDXA, ver. 4.2.0, USA), and total body fat mass (TB-FM) (22) quantities were calculated.

## 27 ***Statistical Analysis***

28 ***Paragraph Number 12.*** Multiple regression analysis (forward method) was used to determine  
29 substantial factors in estimating PTA (i) presence and (ii) severity (area of the PTA within the patellar



1 tendon (24); dependent variables). All independent variables were continuous and included seven  
 2 different three-dimensional variables during the landing phase (knee and hip joint angle, and trunk  
 3 segment angle at IC and at the time of the Knee<sub>Max</sub>, and hip joint angle range of motion (hip joint  
 4 angle at Knee<sub>max</sub> minus hip joint angle at IC)) and five other variables (dorsiflexion, hamstring and  
 5 quadriceps flexibility, maximum vertical jump height, and adiposity). Independent variables identified  
 6 as substantial predictors of PTA presence (0 = no evidence of PTA, 1 = evidence of any degree of  
 7 PTA) from the respective regression analysis were included in a discriminate analysis to correctly  
 8 classify PTA presence using a leave-one-out classification. The validity of two-dimensional data  
 9 collection was determined using a linear regression equation to calculate the magnitude of the  
 10 standard error of the estimate (SEE) between two- (independent variable) and three-dimensional  
 11 (dependent variable) kinematic data. All regressions and discriminate analyses were performed using  
 12 PASW statistical package (Version 17.0.1, SPSS Inc, Chicago, IL). Intra-rater reliability of the lower  
 13 limb and trunk segment two-dimensional kinematic data analysis was assessed for six participants on  
 14 three separate occasions using consecutive trial pairs of the two-dimensional kinematic data (Analysis  
 15 Session 1 and 2; Analysis Session 2 and 3) using the typical error of measurement (TEM; calculated  
 16 as a coefficient of variation), percent change in the mean, and intra-class correlation using Microsoft  
 17 Excel (21).

## 18 RESULTS

19 **Paragraph Number 13.** Means ( $\pm$ SD) of the variables used within the multiple regression analyses to  
 20 predict PTA (i) presence and (ii) severity are illustrated in Table 2. The multiple regression model  
 21 indicated that the substantial predictors of (i) presence (Equation 1) were hip joint ROM ( $R^2=0.474$ ),  
 22 knee flexion at IC ( $R^2=0.112$ ) and quadriceps flexibility ( $R^2=0.090$ ) and, (ii) severity (Equation 2) of  
 23 PTA were VISA ( $R^2=0.392$ ) and hip ROM ( $R^2=0.124$ ), with the standard error of each equation 0.30  
 24 and 12.33 respectively. Discriminate analysis indicated that the respective predictors were able to  
 25 classify the presence of PTA with 95% accuracy and 95% cross-validation.

26 < Insert Table 2 about here >

27 **Equation 1:** Presence of PTA

$$y' = -0.965 + (0.024 \times \text{hip ROM}) + (0.013 \times \text{quadriceps flexibility}) + (0.024 \times \text{knee flexion at IC})$$

28 *Note:* a result that exceeds 1 indicates the predicted presence of PTA. A result of >1 indicates no  
 29 predicted presence of PTA.

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**Equation 2: Severity of PTA**

$$y' = 120.742 + (-1.139 \times VISA) + (0.979 \times hip\ ROM)$$

Note: a result indicates the area, in mm<sup>2</sup>, of PTA.

**Paragraph Number 14.** The two-dimensional kinematic variables showed excellent reliability between Analysis Session 2 and 3 and Analysis Sessions 1 and 2, regarding percent change in the mean, TEM and test-retest correlation (Table 3). The equation of the two-dimensional kinematic data to predict three-dimensional kinematic data is shown in Table 4.

< Insert Table 3 and 4 about here >

**DISCUSSION**

**Paragraph Number 15.** Injuries in sport can substantially affect an athlete's career, which is why many sporting teams have recently adopted a prevention through prediction approach that involves movement screening tools (30). In planning and implementing movement screening assessment tools, it is critical that the influence of injury specific risk factors be identified to enable appropriate modification strategies to be developed and implemented to reduce the risk of patellar tendinopathy. The results of this present study identify substantial variables that enable the prediction of PTA presence and severity in pre-elite basketball athletes, which will allow risk factor modification strategies to be implemented, and therefore enable a prevention through prediction approach to reduce the risk of patellar tendinopathy in athletes.

**Paragraph Number 16.** In identifying variables to predict PTA in asymptomatic athletes, the importance of lumbopelvic control within rehabilitation programs for patellar tendinopathy was confirmed within this present study as the primary risk factor that predicted both the presence and severity of a PTA was hip joint ROM. That is, asymptomatic athletes with a PTA compared to athletes with normal patellar tendons utilized a different hip movement strategy, whereby they displayed a negative hip joint ROM, indicating that they extended their hip joint while landing as opposed to flexing, which was consistent with our previously findings (13). Furthermore, the larger magnitude of this negative hip joint ROM predicted an increase PTA area in participants with a PTA. By utilising this different hip movement strategy, the PTA athletes require greater forward translation of the center of mass in relation to the base of support as the center of mass is at a greater posterior location at IC, which in turn, may increase the tensile and compressive loads on the proximal part of the patellar tendon and contribute to the development of a PTA (13).

1 **Paragraph Number 17.** Asymptomatic athletes with a PTA also landed with greater knee flexion at  
2 IC compared to athletes with normal patellar tendons, which may further contribute to greater tensile  
3 loading of the superficial fibers of the patellar tendon on the anterior surface and contribute to higher  
4 compression of the patellar tendon (2), and also via a greater ratio of the quadriceps tendon force-to-  
5 patellar tendon force (5). As histological adaptations occur as a result of increased patellar tendon  
6 tension and compressive loads (19), this present study provides further evidence that the direction of  
7 the load that the patellar tendon sustains is more critical than the magnitude of this load in the  
8 development of a PTA (13), and the role compressive loads play within patellar tendinopathy  
9 development.

10 **Paragraph Number 18.** Reduced quadriceps flexibility was the only other substantial predictor of the  
11 presence of a PTA in asymptomatic athletes. This supports previous research that has associated  
12 this variable as a risk factor in the development of patellar tendinopathy (6, 39). Although the  
13 relationship between patellar tendinopathy and flexibility is not conclusive, it has been suggested that  
14 reduce flexibility may lead to greater load exerted on the tendon (39). However, asymptomatic  
15 athletes with a PTA have been shown to dissipate similar patellar tendon loads during landing stop-  
16 jump compared to athletes with normal patellar tendons (13), suggesting that quadriceps flexibility  
17 may not affect the magnitude of the load sustained by the patellar tendon during landing. Such a  
18 finding further suggests that quadriceps flexibility may influence the direction of this load, which is  
19 more critical in the development of patellar tendinopathy.

20 **Paragraph Number 19.** Identification of hip joint ROM, quadriceps flexibility and knee joint angle at  
21 IC as meaningful predictors of the presence of a PTA, allows these variables to be used as the  
22 movement screening criteria to predict asymptomatic athletes at risk of developing a PTA. If an  
23 athlete is identified at higher risk of developing PTA (i.e. a result score of  $>1.0$  in Equation 2) risk  
24 modification strategies such as landing retraining can be implemented to potentially reduce further  
25 progression of the asymptomatic PTA into patellar tendinopathy. With an SEE of 0.30 in Equation 2,  
26 a score as low as 0.7 indicates that referral for further biomechanical screening with diagnostic  
27 imaging is warranted. This movement screening criteria is therefore a functional and valid tool that  
28 can be easily implemented at a community sporting level to allow coaches and/or clinicians to screen  
29 their asymptomatic athletes to predict PTA presence, and thereby allowing risk factor modification  
30 strategies to be employed by these athletes at increased risk of developing patellar tendinopathy.

1 **Paragraph Number 20.** In relation to severity of the PTA within asymptomatic athletes, the VISA  
2 score was the second strongest predictor after hip joint ROM. As VISA score is used to aid in the  
3 diagnosis of patellar tendinopathy, with a score less than 80 indicating patellar tendinopathy (38), the  
4 lower VISA predicts a larger PTA area within asymptomatic athletes. While the VISA is a highly  
5 reliable test (37), and is sensitive to changes in severity allowing it to be used to monitor rehabilitation  
6 progress of athletes recovering from patellar tendinopathy (37), the clinical importance of area of a  
7 PTA and VISA in athletes with patellar tendinopathy remains unclear.

8 **Paragraph Number 21.** Although the predictors of the presence and severity of a PTA during landing  
9 were assessed with the criterion of three-dimensional analysis, using a two-dimensional video  
10 analysis to screen athletes at risk would not be valid if there was a lack of consistency between three-  
11 and two-dimensional (29). Nevertheless, within this current study there is consistent relationship  
12 between three- and two-dimensional data indicated by the low SEE, which shows that two-  
13 dimensional data may be used to estimate three-dimensional data with a low amount of error  
14 (between 1.6 – 5.3°, Table 4). Furthermore, the intra-tester reliability of performing the two-  
15 dimensional analysis indicates that there is an excellent reliability for the lower limb and trunk  
16 segments (TEM ~1-2%, Table 3). Therefore, based on the results of this study, it is suggested that  
17 two-dimensional motion analysis is a reliable and valid alternative for coaches and clinicians relative  
18 to the costly criterion three-dimensional motion analysis to predict three-dimensional data values.

19 **Paragraph Number 22.** The authors acknowledge potential limitations within this study. Firstly, the  
20 etiology of diverse types of patellar tendinopathy are suggested to be different (10, 17), and as the  
21 asymptomatic participants with PTA incorporated in this study included both bi- and uni-lateral PTA  
22 athletes. This is suggested to potentially have an influence on the results, although further research  
23 is required. Further limitations of this study include the age and skill level of the target population  
24 included for participation. As participants were limited to junior pre-elite athletes, it is unknown if the  
25 results observed in this study could be replicated in other age groups and/or competition levels such  
26 as elite athletes. Therefore, we recommended that future research investigate an additional  
27 independent sample of athletes to confirm this current study's findings, and based on the three  
28 criterion, development of effective preventative measures are developed to aid in the reduction of  
29 patellar tendinopathy injury.

## 1 CONCLUSIONS

2 **Paragraph Number 23.** With hip joint ROM and knee joint angle at IC during stop-jump landing, and  
3 quadriceps flexibility as significant predictors of the presence of a PTA, and are easily measured and  
4 identified, a simple and reliable movement screening tool incorporating only these risk factors during  
5 the landing phase of a stop-jump has been developed to allow coaches and/or clinicians to screen  
6 and determine the presence and severity of a PTA, and thereby enabling risk factor modification  
7 strategies to be developed and implemented, reducing the risk of developing patellar tendinopathy.

## 8 ACKNOWLEDGEMENTS

9 **Paragraph Number 24.** The authors would like to gratefully acknowledge Michael Jones and PRP  
10 Diagnostic Imaging for the funding of the ultrasounds in this study. There are no other conflicts of  
11 interest from any of the authors. The results of the present study do not constitute endorsement by  
12 ACSM.

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1 CAPTIONS

2 TABLE 1. PTA Measurements.

3 TABLE 2. Means ( $\pm$ SD) of independent and dependent variables included in multiple regression  
4 analysis to predict PTA presence and severity.

5 TABLE 3. Intra-rater reliability of the two-dimensional kinematic data for 6 participants: analysis  
6 sessions 1 v 2 and analysis sessions 2 v 3.

7 TABLE 4. Equations to convert two-dimensional (2D) joint angles to their three-dimensional  
8 equivalent ( $y'$ ) during the landing phase of the stop-jump task.

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