



## Original Research

## The Lower Limb Assessment Score: A valid measure of hypermobility in elite football?

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## ABSTRACT

**Objective:** This study aims to validate the Lower Limb Assessment Score against the current gold standard Beighton Scale within an adult elite footballing population to allow for future research to explore the influence of lower limb specific hypermobility on injury incidence.

**Design:** Observational cohort study.

**Setting:** Thirty-six male, professional footballers aged between 18 and 37 years old.

**Main outcome measures:** The Sensitivity, specificity, positive predictive value, negative predictive value and Spearman's rank correlation between the LLAS and Beighton Scale.

**Results:** There was significant strong correlation between LLAS and Beighton Scale scores ( $\rho = 0.732$ ;  $p < 0.001$ ). The LLAS displayed a sensitivity of 67% and specificity of 94% when a cut off of  $\geq 4/12$  was applied to the screening data. This cut off point also yielded moderate Positive Predictive Validity (50%) and excellent Negative Predictive Validity (97%).

**Conclusions:** The present study suggests that the LLAS is a valid test for identifying lower limb hypermobility within an adult male footballing population when a cut off of  $\geq 4/12$  is used.

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## 1. Introduction

Generalised Joint Hypermobility (GJH) is a physiological entity whereby most synovial joints move beyond their normal limits (Pacey, Nicholson, Adams, Munn, & Munns, 2010). GJH is the most commonly identified using the current gold standard Beighton Scale (Juul-Kristensen, Schmedling, Rombaut, Lund, & Engelbert, 2017). The Beighton Scale also forms part of the criteria for diagnosing Hypermobility Spectrum Disorders (HSD) and Ehlers-Danlos Syndrome-Hypermobility Type (hEDS) (Juul-Kristensen et al., 2017).

The prevalence of Generalised Joint Hypermobility (GJH) within the general population has been widely reported as between 2% and 57% (Remvig, Jensen, & Ward, 2007). This wide range of figures reported by Remvig et al. (2007) is more than likely due to the wide variety of age groups and ethnicities as well as both genders in the

included studies. It is therefore appropriate to consider prevalence within more relevant and specific cohorts. Prevalence of GJH within male football specific cohorts has been reported at 21% (Collinge & Simmonds, 2009) with a 5/9 cut off applied. A higher figure of 33% has been reported within a similar male football cohort (Konopinski, Jones, & Johnson, 2012), however a lower threshold of 4/9 on Beighton Scale was used in that instance. The importance of recognizing which cut off point has been used is highlighted by the work of Simmonds and Collinge (2009) who demonstrated that altering the Beighton Scale cut off point from 4/9 to 5/9 meant that prevalence of hypermobility classification decreased from 42% to 21%.

In a recent large cross-sectional study (Singh et al., 2017) the mean Beighton Scale score decreased as age increased. The authors also found that females and non-Caucasian participants have a higher Beighton Score throughout their lifespan.

The Beighton Scale (Beighton et al., 1973) has been demonstrated as having excellent levels inter-rater reliability within paediatric (Smits-Englesman, Klerks, & Kirby, 2011) and female cohorts (Boyle, Witt, & Riegger-Krugh, 2003). However there is no reproducibility study relating to an adult male population which

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would be particularly relevant within elite or professional football. Despite its apparently high reliability there are issues surrounding the use of the Beighton scale due to its upper limb bias and assessment of only single plane movements (Simmonds, 2017). Arguably therefore it is not very appropriate or specific for assessing elite athletes who sustain predominantly lower limb injuries, such as in football.

The Lower Limb Assessment Score (LLAS) was first described by Ferrari et al. (2005) in a paediatric population, with the screening tool appearing to address the short-comings of the Beighton Scale for sporting populations associated with predominantly lower limb injuries. The LLAS has recently been validated against the Beighton Scale and was able to distinguish a control group from a cohort of likely and known hypermobile adult participants (Meyer, Chan, Hopper, & Nicholson, 2017). The authors of that study (Meyer et al., 2017) also completed a small sample analysis which demonstrate good to excellent levels of intra-rater reliability (ICC = 0.85  $p < 0.001$ ), and although this wasn't the main focus of their study it does appear to support the earlier work of Ferrari, Parslow, Lim, and Hayward (2005).

GJH has been assessed within elite football settings, with previous studies focusing on the effect that GJH has upon injury rates (Konopinski et al., 2012) and either injury severity or sub-optimal healing following injury (Collinge & Simmonds, 2009). Both studies were completed within the setting of individual elite football clubs, where players were screened for hypermobility in pre-season before recording all injuries and reporting on injury rates and incidence respectively. The findings of these studies contradict each other in the fact that Konopinski et al. (2012) found high rates of injury in a hypermobile group, yet Collinge and Simmonds (2009) found injury incidence to be similar in both cohorts, but the severity of injury was greater in the hypermobile group. A potential reason for this lack of consensus could be the use of the Beighton Scale as the screening tool in both studies. The use of the LLAS as a method of screening for GJH may have the potential to produce more consistent findings within injury prevalence studies specifically in sports where lower limb injuries are the most commonly seen injury sites. Determining the appropriate LLAS cut off point for elite male football players would enable researchers and clinicians to use the tool for accurately classifying athletes as hypermobile or not, and to better understand the influence of GJH on lower limb injury incidence and severity in football populations. However, the LLAS has not yet been validated within an adult male sporting population as a screening tool for GJH. Therefore the aim of this study was to validate the LLAS against the Beighton Scale, and identify the appropriate cut off point in order to be able to distinguish between players with and without GJH using the LLAS. A secondary aim of this study was to also determine the specificity and sensitivity of the LLAS.

## 2. Methods

### 2.1. Participants and recruitment

As this was a preliminary assessment of concurrent validity of the LLAS a convenience sample of thirty-six male participants aged between eighteen and thirty-seven years of age were recruited from one English Premier League football club (Table Two). All participants were full time elite footballers in the English Premier League. Participants were recruited and assessed for inclusion during the first day of pre-season testing. Participants were excluded if they had returned from surgery within the previous three months, due to the risks of stressing a recently operated joint to its end of range. The study protocol was approved by the University of Bath Research Ethics Approval Committee for Health.

Participants of the study were provided with an information sheet providing the details of the study content and purpose, and all participants provided written informed consent.

### 2.2. Protocol

The participants subjects were screened using both the Beighton Scale (Beighton et al., 1973) and the LLAS (Ferrari et al., 2005) as part of their preseason testing battery. A single assessor performed the entire testing protocol which included both the LLAS and the Beighton Scale. The assessor was a registered and qualified sport physiotherapist. The order of testing was randomized to reduce any influence of testing order on results. Each participant selected from one of two unlabeled envelopes containing the two screening tools with the chosen envelope being the first tool used. The constituent tests of the Lower Limb Assessment Score were performed in the order that they appear in the study by Ferrari et al. (2005), and the Beighton Scale testing performed in the order within which it is published in the work of Smits-Englesman et al. (2011). Each component of the tests was performed bilaterally before moving on to the next component. All testing sessions were completed over the course of one preseason testing day between the hours of 8am and 2pm. Participants had not performed any physical activity prior to the data collection session, however the time of day at which testing was performed did differ between participants. As an adult population was recruited for the study a cut off point of  $\geq 5/9$  for the Beighton scale was used to determine the presence of GJH (Juul-Kristensen, Schmedling, Rombaut, Lund & Engelbert, 2017).

### 2.3. Statistical analysis

All statistical analysis were conducted using SPSS Volume 24 software (IBM Corp. in Armonk, NY). The level of significance was set at  $p < 0.05$ . Basic descriptive analyses were used for all demographic data. Data are presented as mean  $\pm$  standard deviation unless otherwise stated. A paired  $t$ -test was used to examine differences between the left and right side LLAS. In the event of no statistically significant difference between the two scores, the average two limb score will be analysed out of twelve (Ferrari et al., 2005).

The Beighton Score and LLAS results were assessed for normality using the Shapiro-Wilk Test. Both the Beighton Score ( $p = < 0.001$ ) and LLAS ( $p = 0.003$ ) data were skewed, as a result the Spearman's Rank Correlation ( $\rho$ ) was used for analysis and assessing concurrent validity of the LLAS. Associations were classified as weak, moderate, strong (Mukaka, 2012).

Sensitivity and specificity were determined using the following calculations;

$$\text{Sensitivity} = a \text{ (true positive)} / a+c \text{ (true positive + false negative)}$$

$$\text{Specificity} = d \text{ (true negative)} / b + d \text{ (true negative + false positive)}$$

To calculate the Positive and Negative predictive validity of the LLAS in GJH identification Positive (PPV) and Negative Predictive Validity (NVP) were calculated using the following calculations;

$$\text{PPV} = a \text{ (true positive)} / a+b \text{ (true positive + true negative)} \times 100$$

$$\text{NPV} = d \text{ (true negative)} / d + c \text{ (true negative + false negative)} \times 100$$

A post hoc power analysis was carried out using G\*Power (University of Dusseldorf, Germany). Using the obtained Spearman

**Table 1**  
Participants Demographics.

	Mean (Standard Deviation)
Age (y/o)	24.44 (±4.95)
Height (cm)	183.71 (±6.99)
Weight (kg)	79.95 (±7.74)
Gender	Males- 100%
Ethnicity	Caucasian- 89%
Beighton Score	1.78 (±1.61) (out of 9)
Lower Limb Assessment Score	1.90 (±1.35) (out of 12)

Rank Correlation co-efficient of  $\rho = 0.732$  and the sample size of 36, the power (1- $\beta$ ) for the validation study is 0.99 (Faul, Erdfelder, & Bucher, 2009).

**3. Results**

Participant demographics are illustrated in Table 1. The mean scores for the LLAS were not significantly different between the right and left side ( $R = 1.75 \pm 1.50$ ,  $L = 2.06 \pm 1.55$ ,  $p = 0.194$ ), therefore the average two limb score was used (Ferrari et al., 2005). Three subjects (8%) were identified as positive for GJH when utilising the Beighton Scale with a cut off point of  $\geq 5/9$ .

There was a high prevalence of hypermobility for both knee rotation and hyperextension ranges within this cohort, with the 54% and 42% of the study cohort displaying this trait respectively (Fig. 1).

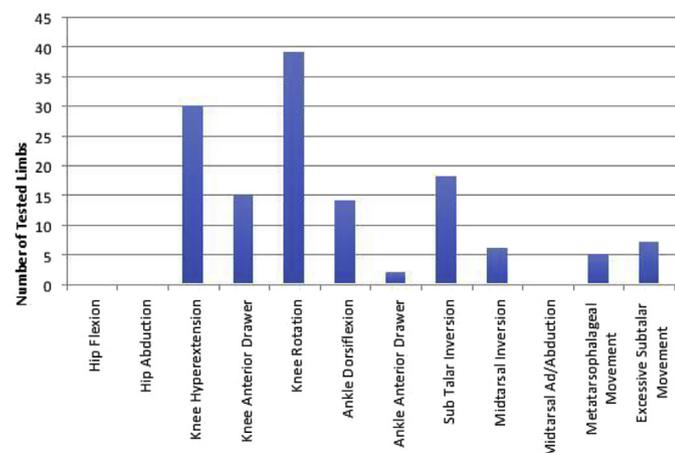
In terms of concurrent validity, the LLAS score had a strong significant association with the Beighton Scale ( $\rho = 0.732$ ,  $P < 0.001$ ), see Fig. 2.

The median and interquartile ranges for the LLAS average score for the non-hypermobility and hypermobility participants as grouped by Beighton Scale results are represented in Fig. 3. This figure suggests that a cut off of between four and five out of twelve would differentiate between the two groups with minimal overlap.

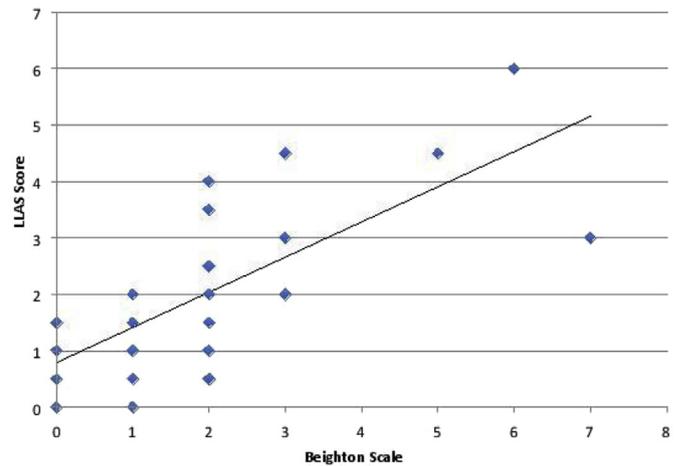
The Lower Limb Assessment Score (cut off of  $\geq 4/12$ ) had a sensitivity of 67% and specificity of 94% when compared with the current gold standard Beighton Scale.

**4. Discussion**

This study was a preliminary assessment of the concurrent validity of the LLAS for detecting GJH in elite male football cohorts. In this study the LLAS was strongly correlated with the Beighton



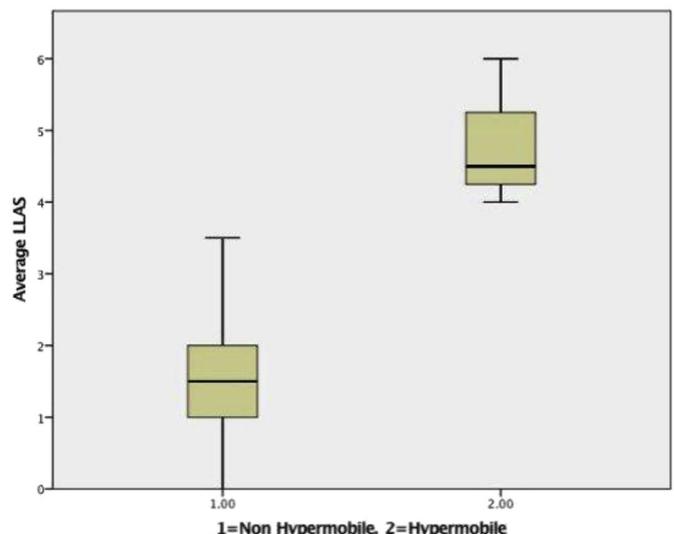
**Fig. 1.** The number of positive tests from the seventy-two limbs tested for each component of the Lower Limb Assessment Score.



**Fig. 2.** Scatterplot of the association between Beighton Scale and Lower Limb Assessment Score.

Scale and appears to be a valid test for assessment of GJH in an adult elite footballing population. The results of this study would suggest that when a cut off of  $\geq 4/12$  is used against the gold standard Beighton Scale, the LLAS displays excellent levels of specificity (94%) and moderate levels of sensitivity (67%) (Table 2). Furthermore, the LLAS shows moderate Positive (50%) and excellent Negative Predictive Value (97%) (Table 3).

As the Beighton Scale is seen as the current gold standard within GJH assessment, it was utilised as the comparison tool to assess the sensitivity and specificity of the LLAS. The Beighton Scale has been used within epidemiological studies for similar cohorts (Collinge & Simmonds, 2009; Konopinski, Graham, Johnson, & Jones, 2016), and therefore would allow for appropriate comparisons of hypermobility prevalence from within those studies. Previous studies have utilised different cut off points to that of  $\geq 4/12$  as proposed within this study. The work of Ferrari et al. (2012) and Chan, Hopper, Zhang, Pacey, and Nicholson (2018) have previously suggested higher cut offs of  $\geq 8/12$  and  $\geq 7/12$  respectively as valid within paediatric and elite dancing settings. Young, predominantly female cohorts would be expected to have a greater number of



**Fig. 3.** Boxplot of the median and interquartile ranges of the LLAS across the Non-Hypermobility and Hypermobility groups as defined by Beighton Scale.

**Table 2**

Sensitivity and specificity of the LLAS at different cut off points against a cut off point of  $\geq 5/9$  for the Beighton Scale.

Varying LLAS Cut Off Point	Sensitivity	Specificity
1	100	15
2	100	55
3	100	85
4	67	94
5	33	100
6	33	100
7	0	100
8	0	100
9	0	100
10	0	100
11	0	100
12	0	100

**Table 3**

Positive and Negative Predictive Values of the LLAS at a cut off point of  $\geq 4/12$  and a cut off point of  $\geq 5/9$  for Beighton Scale.

	PPV	NPV
"Hypermobility" on Beighton Scale	50%	97%

hypermobility joints on testing with Beighton Scale as demonstrated by Chan et al. (2018) who found a significantly greater Beighton Scale Score in females to males (6.2 vs 4.6.  $p < 0.001$ ).

The current study found only 8% prevalence of hypermobility in the elite football cohort using the Beighton Scale cut of  $\geq 5/9$  and  $\geq 4/12$  LLAS. This is significantly lower than previously reported prevalence of 33–42% in similar populations (Collinge & Simmonds, 2009; Konopinski et al., 2012) who reported hypermobility rates of 42% and 33% respectively. It is worth noting that these studies were published prior to the recommendations of Juul-Kristensen et al. (2017). If the cut off points of Collinge and Simmonds (2007) and Konopinski et al. (2012) were changed to that of  $\geq 5/9$  then prevalence rates would reduce to between 21% and 24%, although still much higher than the 8% in the current study. One possibility for the lower rates of hypermobility within this particular study is the higher proportion of Caucasian participants (89%) in this study compared to the previous studies of Collinge & Simmonds (2009) and Konopinski et al. (2012) who reported their cohorts being comprised of 49% and 79% Caucasian participants respectively. It has been shown that Caucasian populations have lower prevalence of GJH (Singh et al., 2017), which would support the lower overall prevalence of GJH found in the current study. Singh et al. (2017) would still report an expected 1% prevalence in an age and gender matched general population cohort and therefore the 8% prevalence in this cohort appears an over-estimation. The reason behind this can only be speculated, but it could be suggested that adult male professional footballers may all have injury histories which could influence the laxity of the injured joints. It is also worth noting that the reported hypermobility rate of 8% is in line with the 9% prevalence found in the larger multi-site study of 80 football players conducted by Konopinski et al. (2016), although it is worth noting that this study used a lower Beighton Scale cut off of  $\geq 4/9$ .

A limitation of this study is the relatively small numbers of participants assessed using the LLAS within a single centre setting. Although this convenience sample size is lower the previous validation study of Meyer et al. (2017) it is in line with a previously published study by Evans, Rome, and Peet (2012). In limiting the study cohort to elite male football players there is potential for selection bias. For this reason it is important to note that the findings may only truly be extrapolated to a wider population if a

wider scale study with participants from different clubs in different parts of the country was performed. The participants of this study however are representative of a standard elite football squad with the gender and age range of the players screened likely to be consistent at all full time elite football clubs throughout the United Kingdom.

The lack of a secondary assessor could be a potential limitation of this study, as this does not allow for analysis of inter-rater reliability within the study. It must also be noted that the use of only one assessor leaves this study at potential risk of assessor bias, with the assessor potentially over-estimating the prevalence of hypermobility. However it could be argued that following the comprehensive use and analysis of the reliability of the Beighton Scale a secondary assessor would not be required. Vallis, Wray, and Smith (2015) reported substantial intra- (ICC = 0.71–0.82) and inter-rater (ICC = 0.72–0.80) reliability of the Beighton Scale in assessment of GJH. Only the Beighton Scale was used for classifying GJH in the current study. This is in contrast to previous studies (Ferrari et al., 2005) where a diagnosis of GJH was also provided using specialist opinion. However within elite sport practice it is unlikely that a rheumatology specialist would be in place as part of a screening protocol, and therefore use of only the Beighton Scale or the LLAS as a first line of identification is valid and applicable to real world scenario. Practitioners working within elite sport may then look to explore referral to a specialist for confirmation of diagnosis if appropriate.

Given that there is a currently a suggestion, but not a conclusion (Konopinski et al., 2016) within the literature surrounding the influence of joint hypermobility on injury rates within football, it is hoped that the validation of a lower limb specific screening tool may help to build the literature base and lead to subsequent epidemiological studies. These epidemiological studies may then be able to identify a potential influence of hypermobility within specific lower limb joints on injury incidence. The proposed link between GJH and increased injury risk comes from an understanding of what is occurring within the passive structures protecting the joint as a result of the condition. With subluxations and sprains common within GJH subjects it is suggested that this trend would continue into a sporting setting (Pacey et al., 2010). Joint subluxations and ligament injuries may arise due to the increase in tissue laxity present due to an abnormal ratio of type III collagen to type I collagen within the tissues (Child, 1986). Type III collagen is a more extensible and disorganised structure than Type I, which means that when stressed there is more mobility present in the affected ligament, for example.

Of particular interest from this study is the high prevalence of joint specific hypermobility within the knee (Fig. 2). Of the seventy-two limbs studied, thirty (42%) displayed greater than five degrees of passive hyperextension on assessment, with an even greater number of tested limbs displaying hypermobility into knee rotation testing (54%). Given that knee hyperextension has been proposed as a risk factor to knee ligament injury (Volpi et al., 2016) due to a lack of active control in this range, the high number of positive tests in this cohort may warrant further research. Previous research has described injury incidence (Konopinski et al., 2012) and even injury rate per 1000 h by joint (Stewart & Burden, 2004), but no analysis has been made between which joints were excessively mobile, and whether or not that influenced injury incidence. It would be of interest for future studies to examine whether the prevalence of knee hyperextension and rotation range is an adaptation to the demands of the sport, with knee hyperextension developing over time in the dominant leg within kicking-related sports for example. Or if prevalence actually even decreases within progressing age groups as these players who may be more prone to serious ligament injuries drop out of the sport.

The findings of this study contribute to the understanding of GJH in elite male footballing populations. Previous work in this field has utilised the Beighton Scale which does not appear to be an appropriate tool for a sport within which lower limb injuries form a majority of the injuries suffered. It is hoped that through validating a tool which analyses a number of lower limb joints in a number of different planes there can be better understanding of which characteristics may predispose footballers to potential injury.

## 5. Conclusion

This study aimed to validate the Lower Limb Assessment Scale in a cohort of elite level, male professional footballers. The screening process identified a score of  $\geq 4/12$  as an appropriate cut off to identify GJH against a cut off of  $\geq 5/9$  for the Beighton Scale.

The results suggest that the LLAS may be an appropriate tool to assess for lower limb GJH within this population. However with recognised limitations to the study it may be appropriate to validate the tool in a wider multi-site population prior to utilising the LLAS for injury epidemiology studies.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pts.2019.03.007>.

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