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Assessing construct validity of the Beighton Score as a measure of generalized joint hypermobility in varsity athletes

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The Beighton Score (BS) is a tool that dichotomizes those who have generalized joint hypermobility (GJH) and those who do not. Unfortunately, the BS is often used in populations that it was not originally developed for, including athletes for screening purposes. The construct validity of the BS remains unknown in this population. This secondary analysis investigated the construct validity of the BS by comparing varsity athletes' passive shoulder and hip ranges of motion (ROMs) to their respective BS and individual forward bend tests (FBTs). There were statistically significant but weak correlations between shoulder ROMs and the BS (r=0.142, p=0.021). Mean hip ROMs were greater by 5-degrees in those with positive FBTs compared to those with negative FBTs. This difference falls within typical measurement errors that occur in practice. Therefore, our results do not

Évaluation de la validité de construction du score de Beighton en tant que mesure de l'hypermobilité articulaire généralisée chez les athlètes de haut niveau.

Le score de Beighton (BS) est un outil qui permet de distinguer les personnes souffrant d'hypermobilité articulaire généralisée de celles qui n'en souffrent pas. Malheureusement, le score de Beighton est souvent utilisé dans des populations pour lesquelles il n'a pas été conçu à l'origine, notamment les athlètes, à des fins de dépistage. La validité de construit du score de Beighton reste inconnue dans cette population. Cette analyse secondaire a étudié la validité conceptuelle du score de Beighton en comparant les amplitudes de mouvement passives de l'épaule et de la hanche des athlètes universitaires à leur score de Beighton et à leurs tests individuels de flexion avant. Des corrélations statistiquement significatives mais faibles ont été observées entre les amplitudes de mouvement des épaules et le score de Beighton (r=0,142, p=0,021). Les amplitudes moyennes de flexion de la hanche étaient supérieures de 5 degrés chez les personnes ayant subi un test de flexion avant positif par rapport à celles ayant subi un test de flexion avant négatif. Cette

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support the construct validity of the BS as a measure of GJH in healthy athletes.

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différence s'inscrit dans le cadre des erreurs de mesure typiques qui se produisent au cours de la pratique. Par conséquent, nos résultats ne confirment pas la validité conceptuelle du score de Beighton en tant que mesure de l'hypermobilité articulaire généralisée chez les athlètes en bonne santé.

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MOTS CLÉS : Score de Beighton, validité de construit, hypermobilité articulaire généralisée, hypermobilité, amplitude de mouvement, sport

Introduction

Joint hypermobility is a trait of an individual who exhibits joint ranges of motion (ROMs) that exceed an accepted normal ROM for a particular joint.[1] Joint hypermobility may be localized to a single joint or occur at several joints in the body, which is referred to as generalized joint hypermobility (GJH). GJH is a trait of certain connective tissue disorders, such as Ehlers Danlos Syndrome (EDS) however it may also exist to a lesser degree in those without pathology.[2] Existing literature supports that GJH may predispose one to musculoskeletal pain[2-4], proprioceptive deficits[5], and injury[2,6-9]. In contrast, there is literature to suggest GJH may actually be advantageous in certain sports[10, 11] while possibly decreasing the likelihood of joint and ligament injury[10, 12]. Despite these conflicting observations, the identification of GJH in athletes may still be important.[13] Thus, it is necessary to evaluate the properties of measurement tools that operationalize the construct of GJH.

While there are different approaches used to detect GJH, the Beighton Score (BS) is the most commonly used tool in both research and clinical settings.[6, 14, 15] The current version of the BS is a 9-point scoring tool that was intended to be used for epidemiological screening and includes four bilateral joint measurements and one sagittal plane multi-joint measurement (full forward flexion of the trunk and hips).[16, 17]

The BS has been incorporated into the more comprehensive Brighton Criteria, which serves as the diagnostic criteria for benign joint hypermobility syndrome (BJHS) and the hypermobile subtype of EDS.[14, 18] Previous work has validated the BS as a measure of GJH in children[19]; however, literature reveals discrepancies in the ideal cut-off values that should be used in adults of different ages, sexes and ethnicities, which questions the validity of the BS as a measure of GJH in select populations.[20] Additionally, Malek *et al*.[1] suggest that the joints within the scoring system do not accurately represent the definition of GJH, and thus cannot be used as a direct indicator of GJH. These authors also propose that the BS cannot be used as an indirect indicator of GJH, as a positive BS value is unable to identify all presentations of GJH, including those with hypermobility at joints outside those that are measured in the BS.[1] Thus, false-negative outcomes become possible as individuals may receive a negative BS outcome, despite exhibiting hypermobility at joints outside the scoring system and a clinical presentation that raises suspicion of disease.[1]

Nevertheless, the BS has been widely adopted in the clinical setting. This includes its use as a screening tool for GJH in sports medicine and athletic settings; however, the use of the BS in this context has not been validated. Validity is one of three fundamental properties for a measurement tool and is comprised of several subtypes. Construct validity is one subtype that can be evaluated on the strength of relationships between measurements obtained using the tool and measurements of other variables that are theoretically connected to the construct.[21] Regarding the BS, construct validity refers to its ability to operationalize the construct of GJH. The construct of GJH is theoretically related to ROM measurements at joints that are, and are not, represented within the BS. Thus, construct validity for using the BS in a specific population may be assessed by investigating the strength of its relationships with measurements of joint ROM.

To our knowledge, no previous study has investigated the construct validity of the BS as a measure of GJH in a sample of healthy adult athletes. Thus, the objective of this study was to investigate for construct validity of the BS in healthy adult athletes in two ways. First, we investigated for correlation between participants' BS and their passive flexion ROM at the femoroacetabular and glenohumeral joints. We hypothesized that if the BS exhibits construct validity as a measure of GJH, those with higher scores should exhibit greater ROMs at joints not included in the BS. Second, we compared the joint ROMs of those who scored positive on the forward bend test (FBT) to those participants who scored negative, as the FBT is the only component of the BS that requires motion at the shoulder and hip joints. Therefore, we hypothesized that those with a positive FBT would exhibit larger ROMs.

Methods

Design

This was an exploratory secondary analysis of pre-season screening data from male and female varsity athletes of various sports. All protocols for the original data collection were approved by the research ethics board at the University of Toronto (Protocol #33327). Data used for the current investigation was a subset of a larger database.[22] Deidentified data were electronically transferred from the University of Toronto to the Canadian Memorial Chiropractic College in accordance with an established data transfer agreement between the institutions. The protocols for this secondary analysis were approved by the Canadian Memorial Chiropractic College's research ethics board (REB #2201X02).

Participants

The sample comprised 266 uninjured male (n=169) and female (n=97) athletes from the University of Toronto. Inclusion criteria included sport participation on a varsity athletic team at the time of data collection. Exclusion criteria included the presence of a known injury at the time of data collection that limited involvement in practice or competition. Prior to their participation in data collection, all athletes provided their written informed consent.

Data collection and quality assurance

The original dataset included measurements of active and passive ROMs at various joints, Functional Movement Screen® scores, anthropometric measurements of the upper and lower extremities and BS outcomes. For our study, we used BS data and hip and shoulder flexion ROMs measured in degrees using manual goniometry.

Bilateral passive hip and shoulder flexion ROMs were measured while supine and seated, respectively. Each measurement was obtained with and without multiarticular restraint; however, for the purpose of this study, only measurements without multiarticular restraint were used (e.g., hip flexion with the knee flexed and shoulder flexion with the elbow extended) in hopes of reducing the influence from surrounding biarticular musculature on ROM measurements. Two measurements were recorded for each joint and the mean was calculated for the left and right side separately, which were further combined as an average. This yielded one hip and one shoulder ROM value per participant that was used in the statistical analysis.

The BS was measured using a standardized protocol as described by Juul-Kristensen *et al*.[23], where test component positivity was determined using visual observation and manual goniometry[16, 17, 23] and scored 0 when negative and 1 when positive. Following completion of all nine measurements, the total BS was calculated as an integer value ranging from 0 to 9. For our study, the integer value of the BS and the outcomes of the individual FBT for each participant were used (e.g., positive FBT versus negative FBT).

Prior to secondary analysis, the original measurement data was reviewed by a single investigator (AP) for the presence of missing data, as well as any identifiable data entry or measurement errors. Consensus on the handling of identified errors in the data was achieved through discussion with a second investigator (SH). Participants were eliminated from the analysis for either the shoulder or hip if they were missing both measurements for either the left or right side for the respective joint.

Statistical analysis

All statistical analyses were performed using R (Version 4.2.1).[24] Two analyses were conducted to assess for construct validity. First, the relationship between the overall integer value of the BS and the hip and shoulder flexion ROMs (left and right combined) were evaluated with Spearman's rank correlations. Second, mean hip and shoulder ROMs, standard deviations and 95% confidence intervals were calculated separately for those who scored positive on the FBT and those who did not. Welch's 2-sample t-test was used to compare hip and shoulder ROMs between athletes of these two groups. Effect sizes were determined using Cohen's d.[25] Statistical significance was achieved for all analyses when the p-value was less than 0.05.

Results

Participants

Participant demographics are described in Table 1. There was a disproportionate number of male athletes (n=169) in comparison to female athletes (n=97). There were three sports that contained only male athletes (e.g., football = 86 males, baseball = 7 males, ice hockey = 7 males). There was one sport that contained only female athletes (e.g., field hockey = 7 females).

Data quality

Two-hundred sixty-three shoulder flexion ROM data points were used in the analysis (Table 2). Three male football players were missing all ROM measurements for one or both sides for the shoulder and one erroneous shoulder ROM value was identified in a fourth football player. Two-hundred sixty-six hip flexion ROM data points were in used in the analysis. BS data was complete for all participants, and there were no identified data entry errors.

Beighton Scores

One-hundred twenty-six of two-hundred sixty-six athletes (47%) scored 0/9 on the BS (Figure 1a.). Only 25/266 athletes (9%) scored at least 4/9 on the BS (Figure 1a.). The FBT was the most frequently scored positive component of the BS (Figure 1b.).

Table 1.
Participant demographics

Sport	Sex	Height (m)	Mass (Kg)
All	Total (n=266)	1.77 (0.09)	81.3 (18.4)
All	M (n=169) F (n=97)	1.82 (0.07) 1.69 (0.08)	89.6 (17.3) 66.8 (8.9)
Football	M (n=86) F (n=0)	1.82 (0.06) --	96.6 (17.2) --
Soccer	M (n=21) F (n=26)	1.80 (0.05) 1.67 (0.06)	77.1 (6.6) 65.4 (9.3)
Rugby	M (n=18) F (n=19)	1.77 (0.07) 1.64 (0.05)	87.9 (17.9) 67.7 (11.3)
Volleyball	M (n=10) F (n=14)	1.88 (0.05) 1.78 (0.06)	82.3 (5.4) 66.6 (4.4)
Lacrosse	M (n=13) F (n=11)	1.80 (0.07) 1.67 (0.05)	84.8 (24.1) 68.0 (8.2)
Basketball	M (n=7) F (n=14)	1.87 (0.08) 1.74 (0.07)	84.5 (6.6) 69.1 (9.4)
Field Hockey	M (n=0) F (n=13)	-- 1.64 (0.05)	-- 64.6 (8.3)
Baseball	M (n=7) F (n=0)	1.78 (0.06) --	76.2 (10.1) --
Ice Hockey	M (n=7) F (n=0)	1.84 (0.08) --	87.4 (10.3) --

Abbreviations: m, meters; Kg, Kilogram; n, number of participants; M, Male; F, Female

Table 2.
Descriptive measures of hip and shoulder flexion ranges of motion (degrees) for each sex within each sport. Standard deviations are reported in parentheses.

		Hip				Shoulder			
Sport	**Sex**	**Mean**	**SD**	**CI-LL**	**CI-UL**	**Mean**	**SD**	**CI-LL**	**CI-UL**
All	All	115	(11)	114	117	167	(10)	166	168
All	M	112	(10)	110	113	165	(9)	164	166
	F	121	(11)	119	123	171	(11)	169	173
Football	M	113	(11)	111	115	166	(9)	164	167
	F	--	--	--	--	--	--	--	--
Soccer	M	109	(9)	105	112	163	(9)	159	167
	F	118	(10)	114	122	172	(11)	168	176
Rugby	M	113	(7)	109	116	166	(10)	161	170
	F	117	(11)	113	122	171	(10)	167	176
Volleyball	M	110	(9)	104	115	165	(12)	157	172
	F	125	(9)	120	129	174	(8)	169	178
Lacrosse	M	109	(13)	102	116	163	(7)	159	167
	F	125	(8)	120	130	170	(13)	163	178
Basketball	M	120	(4)	116	123	166	(10)	158	174
	F	122	(12)	116	128	169	(14)	162	177
Field Hockey	M	--	--	--	--	--	--	--	--
	F	125	(11)	119	131	168	(11)	162	174
Baseball	M	112	(10)	104	119	169	(6)	162	171
	F	--	--	--	--	--	--	--	--
Ice Hockey	M	110	(9)	103	117	159	(4)	156	163
	F	--	--	--	--	--	--	--	--

Abbreviations: SD, Standard Deviation; CI-LL, confidence interval-lower limit; CI-UL, confidence interval-upper limit; M, Male; F, Female

Assessment of construct validity

A weak, yet statistically significant, correlation was observed between passive shoulder flexion ROM and the BS (Figure 2a. $\rho=0.142$, $p=0.021$). The correlation between passive hip flexion ROM and the BS was also weak, and not statistically significant (Figure 2b. $\rho=0.111$, $p=0.070$).

Mean hip flexion ROM was greater by 5 degrees amongst those who scored positive on the FBT (Table 3. $p=0.002$, $d=0.44$). Mean shoulder flexion ROM was 2 degrees higher amongst those who scored positive on the FBT (Table 3. $p=0.084$, $d=0.20$).

Table 3.
Hip and shoulder ranges of motion for those who scored positive and those who scored negative on the forward bend test component of the Beighton Score. Means, standard deviations, confidence interval (CI) limits, p-values and effect sizes are reported.

	Hip					**Shoulder**				
	n	Mean (95%CI) (degrees)	Standard Deviation	p	d	n	Mean (95%CI) (degrees)	Standard Deviation	p	d
FB +ve	191	119 (116, 121)	12	0.002	0.44	188	168 (166, 171)	11	0.084	0.20
FB -ve	75	114 (112, 115)	10			75	166 (165, 168)	10		

Abbreviations: n, number of participants; p, significance value; d, Cohen's d effect size; FB, forward bend test; +ve, positive test; -ve, negative test

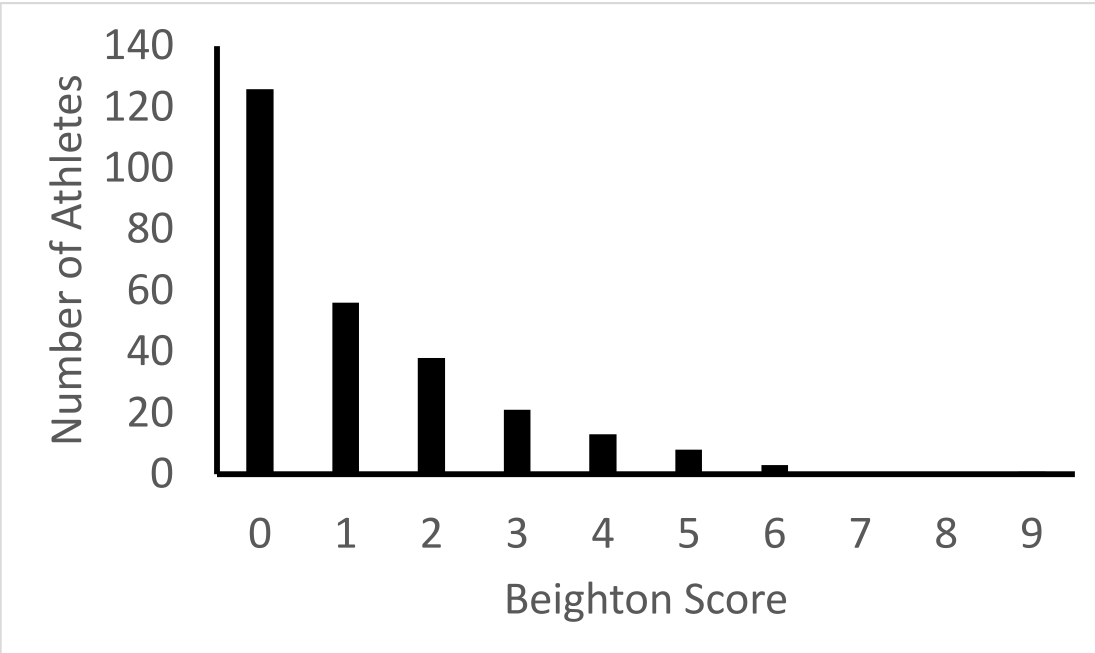

Figure 1a.
Distribution of Beighton Scores amongst athletes.

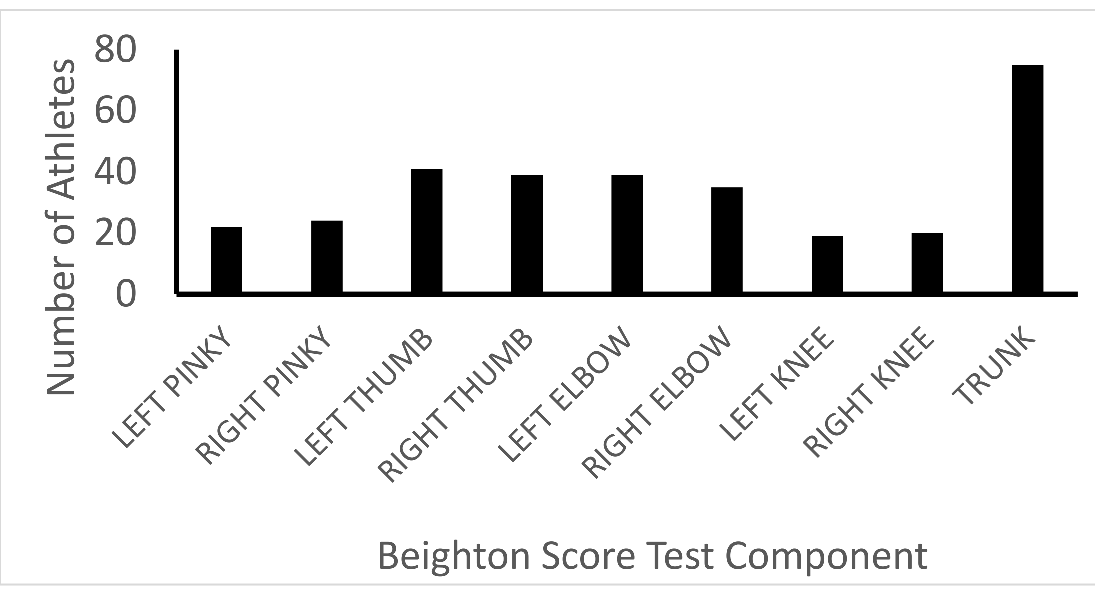

Figure 1b.
Number of athletes scoring positive in each component of Beighton Score.

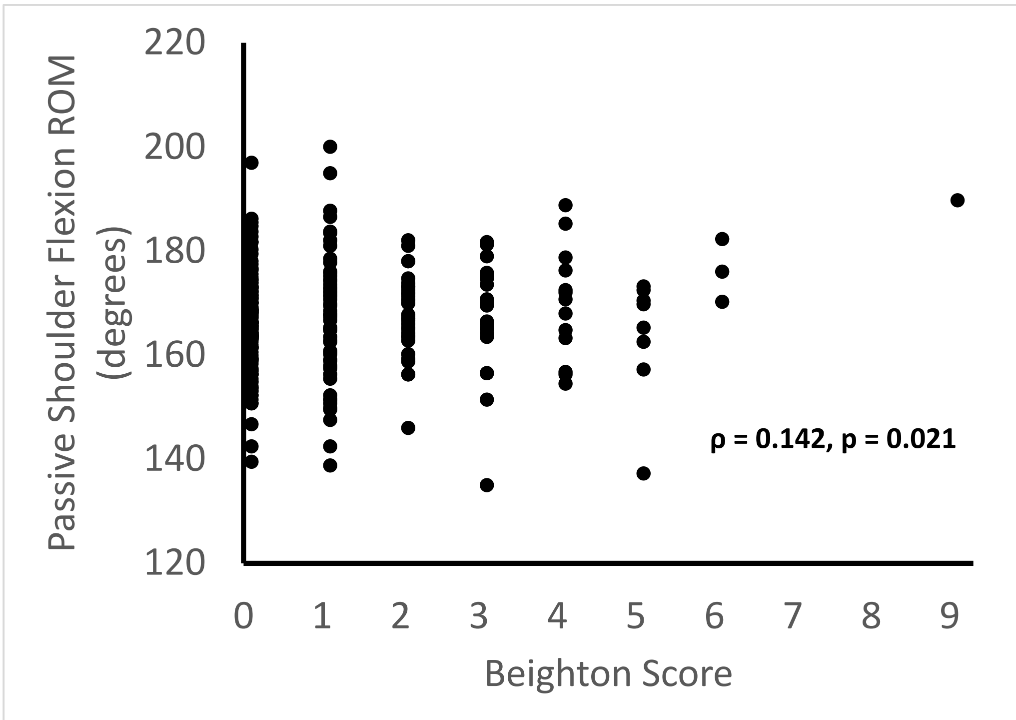

Figure 2a.
Beighton Score versus passive shoulder flexion range of motion.

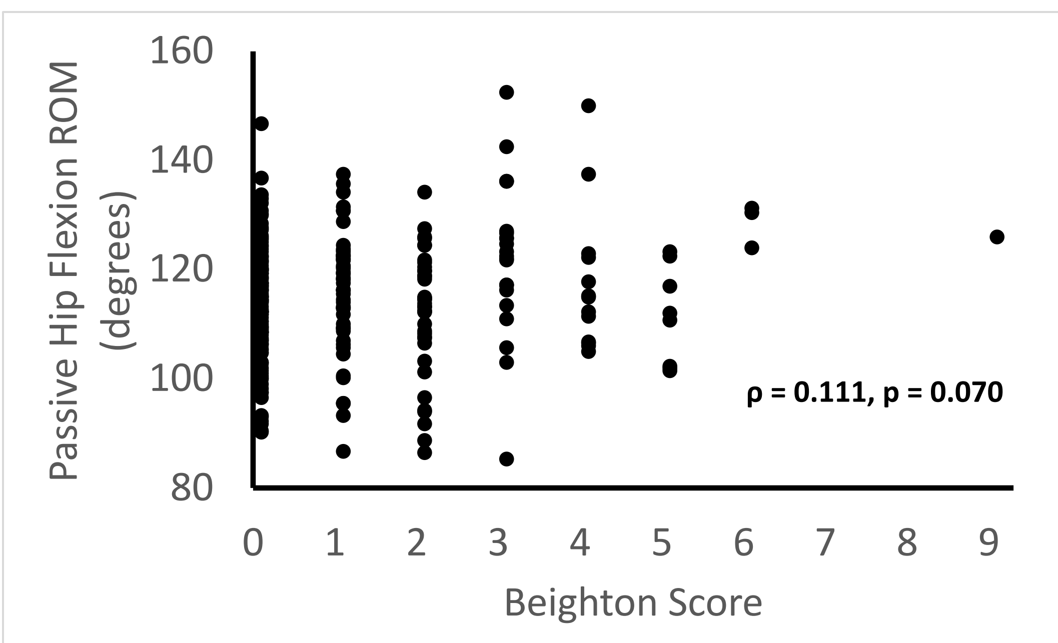

Figure 2b.
Beighton Score versus passive hip flexion range of motion.

Discussion

There remains conflict in the existing GJH literature as some authors suggest that ligament laxity may contribute to musculoskeletal injury[2, 6-9] and pain[2-4], while others suggest it is an asset in certain sports[10, 11] and may prevent ligament and soft tissue injury[10, 12]. Despite these conflicting findings, detection of GJH in athletes may still be important.[13] This relevance has been recognized by clinicians and has resulted in the widespread use of the BS in sport[4, 12, 26-29], clinical[1,18, 30] and research settings[1, 16] without adequate consideration for the validity of the BS as a measure of GJH in these populations. The current study questions the appropriateness of these applications as the results fail to support the construct validity of the BS as a measure of GJH in healthy adult athletes.

Construct validity is determined by relationships between the measurement and other variables/measurements that are associated (either known or theoretical) with the construct.[21] We chose to assess for the construct validity of the BS in two ways. The first was by assessing the strength of an association between the overall BS and ROMs at two large multiaxial joints that are not directly measured in the existing BS. The current assumptions of the BS are that it can be used to operationalize GJH, thus detecting widespread hypermobility even at joints that are not included within the scoring tool.[1, 16, 31] If this is true, one would expect that individuals with a larger BS would exhibit greater ROMs at most, if not all, major joints in the body.

Ultimately, our statistical analyses did not support the construct validity of the BS in our sample population. Although there was a statistically significant correlation between shoulder flexion ROM and the BS, the strength of the correlation was weak and likely a consequence of the study's sample size. Similarly, a statistically significant difference in hip flexion ROMs was observed between those who scored positive on the FBT and those who did not; however, the effect size was small and the 5-degree difference that was identified is within the standard measurement error ranges for manual goniometers[32-34]. For these reasons, we do not believe these results are practically meaningful.

Using the overall BS to assess the association with hip and shoulder ROM is different from the clinical approach that uses standardized cut-off points for the BS to identify people as being hypermobile or not. In conflict with

KEY POINTS

Findings

Our results do not support construct validity of the Beighton Score as a measure of generalized joint hypermobility in healthy adult athletes. Weak correlations exist between passive shoulder and hip ranges of motion and integer values of the Beighton Score in this population. Statistically significant differences exist in mean hip flexion ranges of motion in those with a positive versus negative forward bend test, however the differences fall within standard measurement errors of manual goniometry.

Implications

Statistically significant results may not translate to practical significance when considering range of motion measurement errors that occur in clinical practice. Additionally, the Beighton Score may have little practical use for the screening of generalized joint hypermobility in healthy athletes, as the measurements included in the Beighton Score have been previously described as arbitrary and do not include large multiaxial joints that have high injury prevalence in sport.

Caution

Our study was a secondary analysis of an existing dataset composed of healthy athletes from a limited number of varsity sports with limited joint range of motion measurements. The sample may not have been representative of athletes who are more likely to exhibit joint hypermobility, such as ballet and artistic dancers.

this dichotomous approach suggesting that GJH is an all-or-none phenomena, it is well understood that the hypermobility associated with various hereditable connective tissue disorders falls along a continuum and is not, in fact, simply present or absent.[1] Furthermore, there is no consensus on the ideal cut-off value that should be used to determine the presence or absence of GJH. Existing literature has revealed that mobility status is significantly affected by age, sex and ethnicity[20] and the most used cut-off value for all populations is ≥4/9[1, 20]. However, it has been proposed that a value of ≥7/9 be used for Caucasian children aged 6-12[19], suggesting that the scoring criteria could change throughout one's life. It is for these reasons that the overall BS was used in our study, instead of mobility classification.

The current study being a secondary analysis is its main limitation. This means that we were unable to control what ROMs were collected. For example, data for internal and external rotation ROM values at these joints may have highlighted potential exposure dependent ROM differences in certain athletes, as this has been observed in various sports.[10, 29, 35]

Our sample population was also not representative of certain sports that have been shown to have a high prevalence of hypermobility, such as ballet and artistic gymnastics.[10, 29, 35] This may have resulted in the large number of athletes who scored low on the BS, and therefore our results should not be generalized to all athletic populations. The inclusion of a wider variety of sports to include those that have a higher prevalence of hypermobility may help to further assess for construct validity of the BS as a tool for classifying GJH, as these populations may be unique. We suggest that future works address these limitations.

Conclusion

In conclusion, our results do not support the construct validity of the BS as a measure of GJH in healthy adult athletes. While shoulder ROM was very weakly associated with the integer value of the BS and hip flexion ROM was greater in those who scored positive on the FBT, it is important to consider that reaching statistical significance does not always equal practical significance. These findings question the ability of the BS to serve as an indicator for future injury risk or performance in athletic populations, a purpose it is often used for. Although we did not measure this, we believe it may be inappropriate to use the tool in this context.

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