

Assessment of demographic and pathoanatomic risk factors in recurrent patellofemoral instability

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Abstract

Purpose The WARPS/STAIID classification employs clinical assessment of presenting features and anatomic characteristics to identify two distinct subsets of patients within the patellofemoral instability population. The purpose of this study was to further define the specific demographics and the prevalence of risky pathoanatomies in patients classified as either WARPS or STAIID presenting with recurrent patellofemoral instability. A secondary purpose was to further validate the WARPS/STAIID classification with the Banff Patella Instability Instrument (BPII), the Marx activity scale and the Patellar Instability Severity Score (ISS).

Methods A convenience sample of 50 patients with recurrent patellofemoral instability, including 25 WARPS and 25 STAIID subtype patients, were assessed. Clinical data were collected including assessment of demographic risk factors (sex, BMI, bilaterality of symptoms, affected limb side and age at first dislocation) and pathoanatomic risk factors (TT-TG distance, patella height, patellar tilt, grade of trochlear dysplasia, Beighton score and rotational abnormalities of the tibia or femur). Patients completed the BPII and the Marx activity scale. The ISS was calculated from the clinical assessment data. Patients were stratified into

the WARPS or STAIID subtypes for comparative analysis. An independent *t* test was used to compare demographics, the pathoanatomic risk factors and subjective measures between the groups. Convergent validity was tested with a Pearson *r* correlation coefficient between the WARPS/STAIID and ISS scores.

Results Demographic risk factors statistically associated with a WARPS subtype included female sex, age at first dislocation and bilaterality. Pathoanatomic risk factors statistically associated with a WARPS subtype included trochlear dysplasia, TT-TG distance, generalized ligamentous laxity, patellar tilt and rotational abnormalities. The independent *t* test revealed a significant difference between the ISS scores: WARPS subtype ($M = 4.4$, $SD = 1.1$) and STAIID subtype ($M = 2.5$, $SD = 1.5$); $t(48) = 5.2$, $p < 0.001$. The relationship between the WARPS/STAIID and the ISS scores, measured using a Pearson *r* correlation coefficient, demonstrated a strong relationship: $r = -0.61$, $n = 50$, $p < 0.001$.

Conclusions This study has demonstrated statistically significant evidence that certain demographics and pathoanatomies are more prevalent in each of the WARPS and STAIID patellofemoral instability subtypes. There was no difference in quality-of-life or activity level between the subtypes. The WARPS/STAIID score demonstrated convergent validity to the ISS and divergent validity to the BPII score and the Marx activity scale. This study has further validated both the WARPS/STAIID classification and the ISS of patients that present with recurrent patellofemoral instability.

Level of evidence III.

Keywords Patellofemoral instability · Patellar instability · WARPS/STAIID classification · Patellar Instability Severity Score · Trochlear dysplasia · Patellar tilt

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Introduction

Patellofemoral instability is a common knee problem with significant morbidity [2, 14, 15, 24, 26, 28, 30, 36, 37, 46, 48]. The clinical and biomechanical understanding of instability of the patellofemoral joint is developing, but ideal treatment algorithms remain elusive. One of the greatest difficulties in treating patellar instability is the multifactorial nature of the problem [19, 34, 53]. Numerous pathoanatomies have been postulated to contribute to the risk of instability, despite the fact that causal relationships have not been scientifically established [24]. Several pathoanatomies have been associated with the diagnosis of patellofemoral instability including bony alignment, trochlear dysplasia, rotational abnormalities, patellar alta and patellar tilt [2, 4, 6, 7, 9, 11, 13, 19, 21, 26, 32, 34, 47]. However, the contributions of these and other specific anatomic factors to both the recurrence of patellofemoral instability and clinical outcomes remain relatively unknown.

Pathoanatomic risk factors for recurrent patellar instability may be considered to include all deviations from normal anatomy that influence the function of the patellofemoral joint. Biomechanical studies have demonstrated that both trochlear dysplasia and an increased tibial tubercle to trochlear groove (TT-TG) distance can significantly increase the risk for lateral patellar dislocation [42, 49, 50]. Imaging studies have also demonstrated evidence of an association between abnormal trochlear morphology [1, 29, 32, 33, 51], abnormal patellar morphology [17, 34], patellar tilt [20] and femoral anteversion [5, 40], with the incidence of patellar instability [12, 13, 47]. Other proposed anatomic risk factors include ligamentous laxity [8, 24, 27, 38, 41, 45] and dysplastic quadriceps musculature [11, 39]. In contrast to anatomic risk factors, demographic risk factors such as age, height, weight, body mass index, sex and bilaterality have also been proposed or identified as being associated with the incidence of patellofemoral instability or outcomes following patellar dislocation [2, 15, 25, 26, 43, 52]. Both age and open physes have also been indicated as risk

factors for recurrent patellar dislocation in paediatric studies [18, 26, 31, 32].

The WARPS/STAIID classification (Fig. 1) was introduced in 2013 as a clinical assessment tool that identifies two distinct subsets of patients within the recurrent patellofemoral instability population [21]. WARPS is an acronym that represents five characteristics identified by the clinician: Weak, Atraumatic, Risky anatomy, Pain and Subluxation. STAIID is an acronym for the clinical presentation of: Strong, Traumatic, Anatomy normal, Instability and Dislocation. This classification has demonstrated validity and reliability in patients with recurrent patellofemoral instability [21].

The purpose of this study was to further define the specific demographics and the prevalence of risky pathoanatomies in patients classified as either WARPS or STAIID presenting with recurrent patellofemoral instability. A secondary purpose was to further validate the WARPS/STAIID classification with the Banff Patella Instability Instrument (BPII), the Marx activity scale and the Patellar Instability Severity Score (ISS).

Methods

A convenience sample of 50 patients assessed at a sport-medicine orthopaedic clinic with a confirmed diagnosis of recurrent patellofemoral instability, and a complete dataset for analysis, were assessed. The identified patient cohort included 25 patients of the WARPS subtype and 25 patients of the STAIID subtype. The WARPS/STAIID classification system requires the clinician to score each of the five metrics on a 100-mm visual analogue scale (VAS). These scores are based on the subjective and objective clinical assessment of each patellofemoral instability patient. The five metric scores are summed and converted to a score out of ten, whereby a score of 0–4 represents the WARPS subtype and a score of 6–10 represents the STAIID subtype.

Fig. 1 WARPS/STAIID classification for patellofemoral instability patients

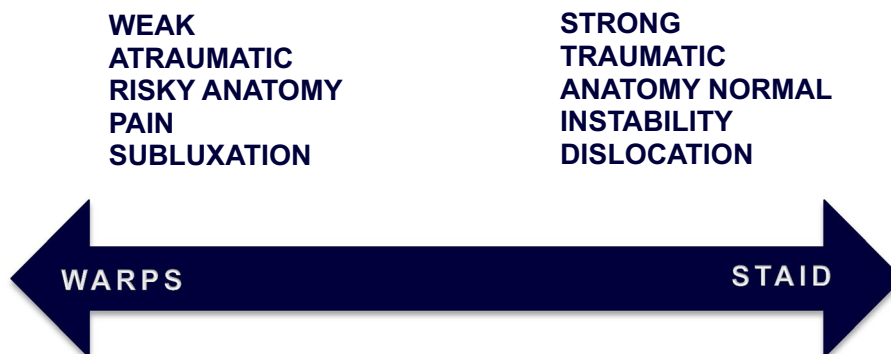


Table 1 Descriptive and comparative analysis of demographic features for patients presenting with patellofemoral instability

Demographic risk factors	WARPS	STAID	<i>P</i> value	**eta-squared	Levene test sig.
Female sex	21/25	16/25	n/a	n/a	n/a
Bilaterality	13/25	4/25	n/a	n/a	n/a
Limb side (R/L)	12:13	10:15	n/a	n/a	n/a
Age at first dislocation mean (SD)	13.4 (4.3)	17.4 (6.9)	0.02	0.11	0.04
BMI mean (SD)	23.5 (4.0)	25.4 (4.2)	0.10	0.06	0.81

n/a the statistical test is not applicable

n.s the results were non-significant

** Only for significant *P* values greater than 90 % CI

Clinical data were collected including demographic risk factors (sex, body mass index (BMI), bilaterality of symptoms, affected limb side and age at first dislocation) and pathoanatomic risk factors (TT-TG distance, patella height, patellar tilt, grade of trochlear dysplasia, Beighton score and rotational abnormalities of the tibia or femur). Trochlear dysplasia was graded as none, low grade or high grade, where high-grade dysplasia represented Dejour types B, C and D [33]. Patellar height was measured on a plain lateral radiograph using the Caton–Deschamps ratio. All patients completed subjective outcome measures including the BPII and the Marx activity scale. The ISS was calculated from the clinical assessment data per Balcarek et al. including age at first dislocation, bilaterality of symptoms, trochlear dysplasia (no, low grade, high grade), patellar height (Caton–Deschamps, TT-TG and patellar tilt [4]. This study received ethics approval from the University of Calgary, Conjoint Health Research Ethics Board and Child Health Research Office (REB15-0616).

Statistical analysis

Patients were stratified into the WARPS or STAID subtypes for comparative analysis. An independent *t* test was used to compare demographics, the pathoanatomic risk factors and subjective measures between the groups. A convenience sample was used for this study; therefore, Levene test for equality of variances and effect size were calculated for significant differences between the WARPS and STAID stratifications. Convergent validity was tested with a Pearson *r* correlation coefficient between the WARPS/STAID and ISS scores. All data, with the exception of effect size, were analysed using SPSS version 22.1 ©. Effect size was manually calculated for eta-squared using the following formula: $t^2/t^2 + (n1 + n2 - 2)$.

Results

The average WARPS/STAID score for the WARPS group was 2.1 (range 0.7–4). The average WARPS/STAID score

for the STAID group was 8.5 (range 6.7–9.9). Comparative analysis of the demographics of patients presenting with patellofemoral instability by WARPS and STAID subtype classification is provided in Table 1. In the WARPS group, there were 21/25 (84 %) female subjects, and in the STAID group there were 16/25 (64 %) females. Thirteen of the twenty-five (52 %) WARPS patients suffered from bilateral symptomatic patellar instability, while 4/25 (16 %) STAID patients suffered from bilateral symptomatic patellar instability. The WARPS patients suffered their first dislocation at an earlier age than the STAID patients. Affected limb side and BMI were not significantly different between the two classification subtypes.

Comparative analysis of pathoanatomic features and subjective outcome measures for patients presenting with patellofemoral instability by WARPS and STAID subtype classification is provided in Table 2. In the WARPS subtype 12/25 (48 %) were identified as having high-grade trochlear dysplasia compared to 7/25 (28 %) in the STAID group. Rotational abnormalities were present on clinical assessment in 11/25 (44 %) of the WARPS patients compared with 5/25 (20 %) of the STAID subtype.

There was no correlation between the WARPS/STAID score and either the BPII score or the Marx activity score. The relationship between the WARPS/STAID and the ISS scores, measured using a Pearson *r* correlation coefficient, demonstrated a strong relationship: $r = -0.61$, $n = 50$ ($p < 0.001$). The negative correlation represents the fact that the higher the WARPS/STAID score, the more those patients had ‘normal anatomy’ (or represented the STAID subtype) while the ISS scores for these same patients would be lower.

Discussion

This study has demonstrated statistically significant evidence that specific demographics and pathoanatomies are more prevalent in each of the specific WARPS and STAID subtypes in patients presenting with recurrent patellofemoral instability. The WARPS group included more females,

Table 2 Comparative analysis of pathoanatomic and subjective measures for patients presenting with patellofemoral instability

	WARPS mean (SD)	STAID mean (SD)	P value	**eta-squared	Levene test sig.
<i>Pathoanatomic risk factors</i>					
Trochlear dysplasia (no/low/high)	2/11/12	6/12/7	n/a	n/a	n/a
TT-TG (mm)	17.1 (5.0)	13.3 (4.8)	0.009	0.14	0.88
Patellar tilt (°)	28.3 (8.3)	16.9 (10.3)	<0.001	0.28	0.21
Rotational abnormalities	11/25 (44 %)	5/25 (20 %)	n/a	n/a	n/a
Patella height (Caton–Deschamps ratio)	1.1 (.12)	1.0 (.11)	n.s.	n/a	0.21
Beighton score/9	4.2 (3.0)	2.4 (2.3)	0.01	0.11	0.13
<i>Outcome measures</i>					
BPII/100	24.4 (13.1)	27.6 (17.2)	n.s.	n/a	0.13
Marx activity scale/16	6.4 (5.4)	7.3 (5.9)	n.s.	n/a	0.44
WARPS/STAID score/10	2.1 (.95)	8.5 (.98)	<0.001	0.92	0.78
ISS/7	4.4 (1.1)	2.5 (1.5)	<0.001	0.36	0.07

n/a the statistical test is not applicable

n.s the results were non-significant

** Only for significant P values greater than 90 % CI

a greater percentage of high-grade trochlear dysplasia, a larger TT-TG distance, increased patellar tilt and a higher Beighton score. The STAID group included more males, a later age of first dislocation, and more unilateral pathology. There was no difference between groups in patella height measures. There was no difference in quality-of-life (BPII score) or activity level between the subtypes. The WARPS/STAID score demonstrated convergent validity to the ISS and divergent validity to the BPII and the Marx activity scores. This study has further validated both the WARPS/STAID classification and the ISS of patients that present with patellofemoral instability.

The ultimate goal of any classification is to be able to guide treatment and to predict outcome. Patients that present with patellofemoral instability may have many, or only a few, predisposing factors. The multifactorial nature of this condition creates a very complex patient population in which to predict outcome. Some groundwork has been laid by studies that have identified certain anatomic features as being associated with patellofemoral instability. Historically, these studies have focused on trochlear dysplasia, TT-TG distance, patellar tilt and patella alta [10, 11, 13, 47]. The ISS expanded this list of predisposing factors, examining age at first dislocation, bilaterality of symptoms, BMI, physical activity score and affected knee. Identifying all the risk factors for patellofemoral instability will be challenging, and clearly not all factors will have the same degree of influence. It is also to be expected that some factors will only contribute to patellofemoral instability risk in combination with certain other pathoanatomic features.

When an association is reported between a risk factor and a condition, this relationship is not necessarily causative. For example, the higher incidence of patella alta reported

in patients with patellar instability, compared to a group without instability, may indicate that patella alta is a risk factor or that the patella alta is a consequence of the instability. Therefore, further exploration of demographics and risky pathoanatomies is required in order to determine the role of each identified factor in terms of contribution to the risk of patellar dislocation. One MRI study that assessed the anatomic risk factors in patients following a lateral patellar dislocation found that patients with trochlear dysplasia and either an abnormal TT-TG distance or patella alta had 37 and 41 times higher risk of recurrent patellar instability, respectively [29]. Interestingly, this study determined that patellar alta and abnormal TT-TG distance were rarely identified as independent risk factors [29]. If it can be determined how a risk factor interacts with other risk factors, and how much each factor contributes to the variance seen in this patient population, thresholds for treatments including surgical management can then be established.

The demographics of patients with recurrent patellofemoral instability are becoming clearer. Consistent with the literature, patients with a greater number of pathoanatomic features (WARPS subtype) demonstrated an earlier age of onset of their instability [4, 15, 26, 31, 32]. Multiple studies have reported a female sex association, the findings of which are consistent with the present study [3, 15, 25]. However, it is important to note that some studies, particularly in younger patients, have not determined an increased incidence in females and therefore further study will be required to verify this risk factor [2, 4, 31, 52]. Affected limb side and BMI were not significant factors between the groups. Although historically associated with patellofemoral instability, BMI requires further investigation to be statistically proven to be a risk factor [24, 43].

This study has confirmed that the prevalence of specific known pathoanatomies is present with higher frequency in the WARPS compared to the STAID subtype of patients with patellar instability. These include trochlear dysplasia, patellar tilt, increased TT-TG distance, rotational abnormalities and ligamentous laxity. The findings regarding trochlear dysplasia are consistent with an increasing volume of the literature, demonstrating that trochlear dysplasia is a very significant risk factor for patellofemoral instability [16, 23, 44, 50]. Interestingly, patella height data did not demonstrate significant differences between the WARPS and STAID subsets. This finding is consistent with the theory that patella alta may actually be an effect of patellofemoral dislocation rather than a cause [18]. The increased patella tilt in the WARPS subset may be accounted for by the higher number of patients with high-grade trochlear dysplasia, potentially resulting in the patella riding on the lateral trochlea and causing increased tilt. The anatomic feature of patellar tilt, like all other identified anatomic characteristic, requires substantially more investigation to determine its relationship with the incidence and outcomes of patellar instability. This study also provides data that rotational abnormalities as well as a positive Beighton score is associated with patellofemoral instability. Although some publications have noted these risk factors, they have not been investigated as significantly as other pathoanatomic features possibly due to the fact they are not routinely assessed.

The BPII is a patient-reported disease-specific quality-of-life outcome measure for patients with patellofemoral instability [22]. The Marx activity scale is a knee-disorder-specific activity score [35]. Both of these subjective outcome measures have been shown to be valid, reliable and responsive to change. In this study, there was no statistically significant difference between the WARPS and STAID subtypes in either the BPII score or Marx activity scale, indicating that these subjective measures were not able to predict the WARPS or STAID subtype. This comparison of the WARPS/STAID classification to two subjective measures provides an assessment of divergent validity. It is important to note that these findings are expected given that the WARPS/STAID score is based on patellofemoral instability risk factors, while the BPII score and Marx activity scale assess quality-of-life and activity level, respectively.

Published in 2014, the Injury Severity Score (ISS) was developed by Balcarek et al. in order to identify which patients with a first-time patellofemoral dislocation were likely to redislocate [4]. Both the WARPS/STAID classification and the ISS were created in an effort to determine which pathoanatomic features and demographic risk factors may predict outcomes and therefore could be used to guide the treatment of patellofemoral instability. The strong relationship noted in this study between the WARPS/

STAID score and the ISS provides a measure of convergent validity. The fact that these tools were assessed as having a ‘strong’ as opposed to a ‘very strong’ correlation can be explained by the fact these tools measure similar but not exact features. The ISS specifically considers age and bilaterality of symptoms and provides weighting within the score to TT-TG distance, trochlear dysplasia, patellar alta and patellar tilt [4]. The WARPS/STAID classification takes into account neuromuscular control, differentiates between traumatic and atraumatic onset of symptoms and considers a greater range of pathoanatomic features including generalized ligamentous laxity, rotational abnormalities of the femur and tibia, and foot pronation [21]. The WARPS/STAID classification assesses patients with recurrent patellofemoral instability, while the ISS examines risk factors related to recurrence after a first-time patellofemoral dislocation. In spite of this, both systems assess the role of risky demographic and anatomic features in patellofemoral instability patients. The fact that there is a statistically significant relationship between the two provides concurrent validation of both scoring systems.

The WARP/STAID classification was designed to identify two distinct subtypes that exist in the patellofemoral instability population. This study has confirmed the utility of the classification by establishing convergent and divergent validity. It is clear, however, that the constructs developed and evaluated in the WARPS/STAID classification will require further refinement with regard to specific descriptions as well as the weighting of each metric. In the initial validation, the metrics were weighted equally. Based on recent research publications, it is likely that the anatomy metric will be most important in determining the overall WARPS/STAID score. Within the anatomy metric, certain pathoanatomies such as trochlear dysplasia may require a higher weighting than others. Future research will be necessary to hone the classification to improve its utility and predictive value. Overall however, the WARPS/STAID classification continues to demonstrate validity in patients with recurrent patellar instability.

Limitations of this study include that a convenience sample was used for the analysis. Considering that the risk factors for patellar instability are not entirely proven, it was difficult to match the groups because the presenting characteristics are known to differ between the WARPS and STAID subtypes. In addition, some reported risk factors for patellofemoral instability were not evaluated, such as open physes and patellar morphology. This study also intentionally avoided selecting patients that presented with a mix of WARPS/STAID characteristics. For the purpose of this study, a homogenous group of WARPS and STAID patient subtypes was selected to enable assessment of distinct pathoanatomic features. Including the mixed group of patients in future analysis may add further information.

Conclusion

Patients presenting with patellofemoral instability possess demographic and pathoanatomic risk factors of variable severity and frequently in combination. Certain combinations of these risk factors have a potentially greater influence on the recurrence of instability and outcomes following injury. This study has demonstrated statistically significant evidence that certain demographics and pathoanatomies are more prevalent in each of the WARPS and STAID patellofemoral instability subtypes. There was no difference in quality-of-life or activity level between the subtypes. The WARPS/STAID score demonstrated convergent validity to the ISS and divergent validity to the BPII score and the Marx activity scale. This study has further validated both the WARPS/STAID classification and the ISS of patients that present with recurrent patellofemoral instability.

Compliance with Ethical Standards

Conflict of Interest No conflict of interest, financial or other, exist.

Funding There was no funding sought or received for this study. All authors listed have contributed sufficiently to the project to be included as authors, and all those who are qualified to be authors are listed.

Ethical approval This study was approved by the University of Calgary Conjoint Health Research Ethics Board and the Child Health Research Office (Ethics ID 24393).

Informed consent Informed consent was obtained from all patients.

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