Validation of a new method of evaluation of the sensorimotor control of the shoulder in unstable subjects.

Introduction  
  
Objective assessment of shoulder instability is necessary to guide diagnosis and treatment recommendations. The management of the first episodes of instability of the traumatic anterior shoulder (TASD) remains controversial. For some patients, surgical treatment should be proposed from the outset in male, active and athletic patients, since recurrences are high (33% to 92% 1,2). For others, the initial treatment consists of rehabilitative management 3. There are few recommendations for evaluation and protocols for the rehabilitation of the unstable shoulder 3–5, while studies based on neuromuscular control Chronic ankle or knee instability have been validated, improving functional abilities and quality of life markers (QoL) 6,7.  
The shoulder is stabilized by the passive elements, and especially by the dynamic elements: the muscles and their tendons. Only subjective clinical tests are not correlated with the severity of lesions, reduced participation in physical activities or daily tasks, or the risk of recurrence of recurrence 8. Clinical symptoms are not necessarily related to lesions of the anatomical structures, but may be due to alterations or misuse of neuromuscular control. Neuromuscular control includes proprioception information, central integration and neuromuscular response 9. The importance of sensorimotor control is major in maintaining joint stability. Several authors have proposed research methods to study each of these components independently 9–11. Only Edouard et al proposed a global study of this control system and showed that recording by a force platform was reliable, reproducible and feasible in subjects with anterior shoulder instability 12. There were some limitations regarding the study position.  
In order to overcome these limitations, a new method allowing the study of the center of pressure (CoP) of the instability of the shoulder was proposed by freeing itself from the postural control of the balance by a recording in a sitting position. Also, to be clinically relevant, recording was performed in the apprehension position (abduction of 90 ° and external rotation) in which the anterior instability increases 13,14. More, the application of different charges on the shoulder complex made it possible to sensitize this clinical test and study it under different conditions.  
The reproducibility and reliability of the method should be tested in subjects with shoulder instability so that they can be used in clinical practice. Indeed, any muscle compensation of the trunk related to the discomfort of the position could make the test non-reproducible.  
In this context, we propose to validate a new method of studying the sensorimotor control of the unstable shoulder in subjects with anterior instability of the shoulder. We want to test the hypothesis that it is a reproducible, reliable and clinically relevant test. This assessment will allow a better understanding of sensorimotor control in subjects with anterior shoulder instability and their assessments and treatments.

Method  
  
Presentation  
We recorded the ground reaction forces of a patient population with anterior shoulder instability in a sitting position.

Population  
Patients were recruited from the clinical activity of an orthopedic and trauma surgery department of a university hospital. Fifteen patients with anterior shoulder instability were included in this cross-sectional study. The inclusion criteria were unidirectional, involuntary, dynamic and trauma-induced instability in patients aged 18 to 40 years.  
The exclusion criteria were the presence of other osteo-articular, muscular, inflammatory or neurological pathologies, in particular the scapular belt. The history of acute or chronic osteo-articular pathologies found by interrogation were exclusion criteria.  
  
Clinical evaluation

A clinical evaluation was performed by a single evaluator, orthopedic surgeon, to describe the population. The joint amplitudes (active anterior elevation and external elbow to the body) were measured using a goniometer. The stability of the shoulder was tested by apprehension, relocation test and anterior release test 8,15.  
 We carried out clinical tests to eliminate a subacromial or internal conflict (Hawker's test, Neer's test), rotator cuff tendinopathy (Jobe's test)A. Shoulder pain or the positivity of one of these tests was an exclusion criterion.  
To assess the quality of life associated with the upper limb, patients completed two questionnaires. We used the DASH (Disabilities of the Arm, Shoulder and Hand tool) score 16. The highest score was 0, and 100 was the most severe. A quality of life score related to shoulder instability was calculated, the Western Ontario Shoulder Instability Index (WOSI) score 17,18. The highest possible score was 0 which means that the patient did not show any QoL related to his shoulder. The score reflecting the greatest decrease in his QoL was 100% of 2100 points.  
Patients were informed of the progress of the study and written consent was obtained prior to the evaluation. The study protocol was approved by a local ethics committee.  
The characteristics of the population are reported in Table 1.

Experimental protocol

The subjects were sitting on a rigid chair fixed to a platform of strength. The tested shoulder was positioned in the position of instability in lateral abduction at 90 ° and in external rotation at 90 °, elbow flexed at 90 ° (figure 1). A horizontal force of posterior direction (perpendicular to the plane of the arm and forearm) was attached to the subject's hand. The force was created by a load attached to a pulley behind the subject. The tests were performed according to 4 loading conditions: 0, 1, 2 and 3kg. A warm-up period of 3 minutes allowed the subjects to familiarize themselves with the position and the various loads. The order of conditions was randomized. Each condition was tested 3 times for each side, representing 24 evaluations per subject. The subjects were asked to fix a target at 1.2 m in front of them at eye level. The instruction given was to keep this position stationary during the test. Each evaluation lasted 32s with a rest period of 1 minute between trials to exclude muscle fatigue. A direct control of the operator was carried out in order to validate the position and its maintenance during the test.  
Pain or apprehension led to the termination of the assessment.  
We conducted assessments under "open-eyes" conditions. Indeed, previous work reports that in the seated position there is no difference between the conditions "open eyes" and "closed eyes" concerning the measurements of the time domain as for the frequency domain during postural resting 19.

The study of the neuromuscular control of the shoulder in a seated position makes it possible to dispense with the postural control of maintaining the equilibrium position of the standing station 19. Indeed, the seated position, with respect to the standing position, Is more mechanically stable, due to a lower center of mass and higher joint stiffness. The seated position therefore requires less neuromuscular control and the evaluation of the shoulder is more easily isolated.  
  
  
  
Equipment  
An AMTI strength platform (Newton, MA, USA) of 40cm \* 60cm was used. The signals were processed and analyzed using a MATLAB program (The Mathworks, Inc., Natick, MA). The low-pass filter was used to calculate the Hz low-pass filter. Ten seated balance parameters

Results  
  
One patient was unable to perform the test with an applied mass of 3kg. In the maximum armed position, apprehension was not bearable by the patient. Data for this condition were not included.  
  
Table 2 reports the ICC values ​​for each of the parameters under the shoulder load conditions of 0, 1, 2 and 3 kg. The ICC values ​​of the mean COP positions were very good at 1 kg (COP AP mean and COP ML mean). The mean position of the COP in the anteroposterior and mediolateral direction represent the stability of the subject in maintaining posture. The high ICC value of these parameters demonstrates that the patient's position is maintained and controls the absence of change in the study position. It also reflects the absence of discomfort which would have required the compensation by the trunk of the posture. For the other parameters, the lowest values ​​were found when applying a mass of 0 kg with moderate or poor fidelity. With a load of 1kg, the parameters had a very good or good and moderate fidelity for the COP range and Tz centered.

The correlation coefficients showed that there was a strong or moderate significant positive correlation between the clinical score of WOSI and the COP AP range, COP area, COP ML range, Tz range and Tz centered rms (Table 3). There was no correlation of the WOSI score with mean AP COP (-0.086), mean COP ML (0.344).

Discussion  
  
Our study evaluated a new method for exploring sensorimotor control in subjects with anterior shoulder instability. The very good or good CCI values ​​of the test-retests show that it is a reliable and reproducible evaluation method. In addition, strong or moderate association with clinical quality of life scores allows us to validate this technique as clinically relevant.  
  
The ICC values ​​(Table 2) show that the evaluation test was reproducible for loads of 1 to 3kg. Concerning the 0kg condition, the COP range, COP speed, COP lenght and Tz centered parameters were considered moderate and Tz centered mediocre. The best values ​​were found in condition 1 or 2 kg. With a load of 3kg, the fidelity values ​​decreased. It is understood that the maximum load of 3kg could be more difficult to bear for the patient, although only one could not perform the test in this condition. The lower fidelity in the 0 kg condition could be explained by the fact that the afferents of the non-stimulated shoulder did not provide to stabilize the shoulder in equilibrium position 20. Indeed, the mechanoreceptors are present in the articular structures and musculo-ligament. In the absence of instability forces applied to the shoulder, joint and ligamentous structures are not stressed, mechanoreceptors are non-activated and sensory information about proprioception (which includes sensation of resistance 19) are not emitted and do not result in a suitable stabilizing neuromuscular response 10.  
The position of the average COP representing the position of the subject on the support is also a variable to control the reliability of our test. Indeed, discomfort or pain during the maneuvering could lead to a displacement of the position of the center of mass (CoM) and the CoP. Moreover, the increase of the load during the tests could displace the CoM and CoP either by compensating for the posture of the subject in reaction to the load or by discomfort causing a rotation of the trunk in order to reduce the external rotation of the shoulder. The high ICC values ​​of the CoP position AP and ML reflect the retention of the trunk posture from the zero-load condition to the 3kg load.

There was a strong significant or moderate positive correlation between the clinical score of WOSI evaluating QoL and COP AP range, COP area, COP ML range, Tz range and Tz centered rms. Our results demonstrated the clinical relevance of the test. There was a positive association. The greater the QoL involvement of the shoulder, the greater the displacement area of ​​the COP in the anteroposterior plane as in the mid-lateral plane. We have seen that the reproducibility of the position of the CoP ML and AP was very good and that the posture was not modified between the tests. The absence of correlation between the clinical scores and the CoP mean values ​​AP and ML, confirms the clinical relevance of our results: the mean position of CoP (reflecting posture) was not correlated with clinical instability.

Our experimental protocol was thus controlled, reproducible and valid. The reaction forces measured reflect the forces and moments of force applied by the muscles on the shoulder.

Anterior dislocations of the shoulder are frequent and affect the quality of life of patients. The standardized assessment can be used to develop a rehabilitation program for neuromuscular shoulder control.

There is nowadays no objective way of assessing instability. In clinical practice, the clinician asks for the number of instabilities and the QoL questionnaires. The clinical examination provides information on the function of the shoulder (joint amplitudes, strength) and on the reproduction of an apprehension indicating instability. Radiological criteria (Hill-Sachs or Bankart fractures) help to assess the risk of recurrence. The couple of moments produced ensures the stability of the humeral head on the small glenoidal articular surface, constantly controlling its centering and its balance. Neuromuscular control and its evaluation are therefore essential to the stability of the shoulder. There are no objective neuromuscular parameters to evaluate these factors. Our study also participates in validating a method of measuring the neuromuscular control of the shoulder and the unsteady shoulder. The free moment (Tz), the moment of force around the longitudinal axis relative to the point of application of the CoP, reflects muscular action and neuromuscular control of shoulder stability in response to posterior horizontal luxating force. Indeed, the stability of the shoulder is ensured dynamically by the activity of the muscles of the rotator cuff, and particularly of the internal and external rotators.

A limitation of our study concerns the position of apprehension during the test. This did not include horizontal abduction corresponding to the position of sporting apprehension. Indeed, during the application of a posterior horizontal abduction, during our pilot tests, the unstable subjects presented a discomfort or pain which could disrupt the test. As some authors, we assume that arm posture without posterior abduction would be clinically relevant, comparable to the physiological situation of instability and comfort 21. Thus, in order to reproduce the position most accurately between subjects, Position involving body segments orthogonal to each other.

Table:  
  
Table 1: Clinical characteristics of the study population.

Table 2: Intra-class correlation (ICC), 95% Confidence Interval (CI), Standard Error of Measurements (SEM) and Coefficient of variation (CV) values of all parameters with loads varying from zero to 3 kg. Values are presented as ICC (lower-upper 95% CI) and% SEM -% CV. CoP: Center of pressure, AP: antero-posterior, ML: medio-lateral, Tz: free moment, ICC: intra-class correlation.

Table 3: Correlation of parameters and clinical scores: Pearson coefficients r (13).