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ORIGINAL ARTICLE

Adult women with mitral valve prolapse are more flexible

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Background: Mitral valve prolapse (MVP) is common in women. Other clinical features such as flexibility and hyperlaxity are often associated with MVP, as there is a common biochemical and histological basis for collagen tissue characteristics, range of joint motion, and mitral leaflet excursion.

Objective: To confirm whether adult women with MVP are more flexible and hypermobile than those without.

Methods: Data from 125 women (mean age 50 years), 31 of them with MVP, were retrospectively analysed with regard to clinical and kinanthropometric aspects. Passive joint motion was evaluated in 20 body movements using Flexitest and three laxity tests. Flexitest individual movements (0 to 4) and overall Flexindex scores were obtained in all subjects by the same investigator.

Results: Women with MVP were lighter, less endomorphic and mesomorphic, and more linear. The Flexindex was significantly higher in the women with MVP, both absolute (48 (1.6) v 41 (1.3); $p < 0.01$) and centile for age (67 v 42; $p < 0.01$) values. In 13 out of 20 movements, the Flexitest scores were significantly higher for the women with MVP. Signs of hyperlaxity were about five times more common in these women: 74% v 16% ($p < 0.01$). Scores of 0 and 1 in elbow extension, absence of hyperlaxity, and a Flexindex centile below 65 were almost never found in women with MVP.

Conclusion: Flexitest, alone or combined with hyperlaxity tests, may be useful in the assessment of adult women with MVP.

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The mitral valve apparatus is a complex structure composed of an annulus, mitral leaflets, chordae tendinae, papillary muscles, and left ventricular, atrial, and aortic walls. Deficiency or degeneration of one or more of these structures may result in dysfunction of the valvular apparatus leading to an abnormal protrusion of one or two valve leaflets into the atrium during ventricular systole, characterising the mitral valve prolapse (MVP).¹ Diagnosis may be made by auscultation of a mid-systolic click and late systolic murmur and confirmed by echocardiographic demonstration of M mode late systolic prolapse and two dimensional leaflet billowing into the left atrium. MVP has been reported to occur in 5–15% of the general population² and often associated with serious complications.³ The reported high prevalence and complication rates of MVP have been challenged by the findings of the Framingham Heart Study, which was conducted in a white population with more stringent echocardiographic criteria.^{4–5} It is currently believed that MVP is at least three to four times more common in women than men, affecting 1–5% of women.^{6–7} In the vast majority of affected subjects there are no significant symptoms and the clinical prognosis is excellent.⁸

Women with joint hypermobility may present with changes in connective tissue not only in the structures directly involved with locomotion, but also in other body systems.^{9–11} It has previously been suspected that women with MVP have higher ligamentous laxity^{9–10} and often higher overall flexibility. There may be a common biochemical and histological basis for collagen tissue disorders that affect joint range of motion and mitral leaflet excursion,¹² making women with MVP more flexible than the general population. Although Jessee *et al*¹³ and Marks *et al*¹⁴ did not find hypermobility among male and female adults with MVP, other authors have.^{9–15–16} For example, Grahame *et al*¹⁷ suggested that the incidence of MVP in hyperflexible people is 2–10 times higher than in people of the same age without hypermobility. Cohen *et al*¹⁸ reported a very high prevalence of

MVP (42%) in a sample of 44 female professional ballet dancers, a section of the population who usually have high levels of body flexibility and leanness. There is also a trend toward lower body mass index in subjects with MVP.^{2–19}

By reviewing data from a comprehensive medical and functional evaluation, we assessed whether adult women with MVP have higher overall and specific joint movement flexibility.

METHODS

We retrospectively studied 125 adult women (mean age 50 years (range 19–74)) who completed a comprehensive medical evaluation (table 1) between August 1998 and October 2000 for clinical reasons (preventive check up, clinical diagnosis, before initiation of an exercise programme). MVP had previously been diagnosed from clinical and echocardiographic findings in 31 of them.

Most of the procedures are widely used and do not require detailed explanation. Both the sitting-rising test and the 4 second exercise test have been fully described elsewhere.^{20–22} For evaluation of flexibility, the main focus of this paper, we used two different procedures: the Flexitest^{23–24} and simple hyperlaxity tests.²⁵

The Flexitest is a dimensionless test, as results are presented as points, with no linear or angular unit featured. It consists of the measurement and assessment of the maximum passive range of motion of 20 joint movements of the body, encompassing the ankle, knee, hip, trunk, wrist, elbow, and shoulder joint. Eight movements are of the lower limbs, three are related to the trunk, and the remaining nine are of the upper limbs. The movements are listed according to roman numbers, from a distal to a proximal sense. Table 2

Abbreviations: BSVI, between segment variability index; DPVI, distal-proximal variability index; FEVI, flexion-extension variability index; IJVI, interjoint variability index; IMVI, intermovement variability index; MVP, mitral valve prolapse

Table 1 Procedures used in the comprehensive medical evaluation

Kinanthropometric measurements	
1.	Body stature and weight
2.	Heath-Carter anthropometric somatotype
3.	Sitting-rising test (evaluation of ability to sit on and rise from the floor)
4.	Flexitest (passive maximal range of motion in 20 body movements)
5.	Thumb, little finger, and elbow joint laxity tests
Clinical information	
6.	Anamnesis
7.	Physical examination
8.	Resting spirometry
9.	Resting and exercise electrocardiograph
10.	Evaluation of cardiac vagal responsiveness (4 second exercise test)
11.	Maximal cardiopulmonary exercise test (cycle ramp protocol)

presents the joint involved and the kinesiological description of the 20 movements that comprise the Flexitest.

For each of the movements, there are five scores to rate flexibility measurements, graded from 0 to 4 in a crescent mobility order. The measure is taken passively, through a slow and gradual performance of the movement until the maximum range. Once the maximum amplitude is reached, it is compared with the evaluation maps (see examples in figs 1 and 2).

A numerical grade is ascribed whenever the amplitude reached equals that in the evaluation map. For instance, when the amplitude reaches position 2 of the map, grade 2 is given until the maximum range of motion reaches the level of score 3. There are no fractional or intermediate values, neither does the scoring take into account the closest grade of the scale. Therefore, only upon actually reaching the specified level for a score is that score given; otherwise, even if the movement is close to the following score, it is rated according to the lower score.

Traditionally, the Flexitest is applied only to the right side of the body, as very seldom, such as in extremely different conditions of use or because of disease, are there significant bilateral differences. Also, for the sake of standardisation, no previous warm up is allowed. The time taken to apply the test varies according to the evaluator's experience and the condition of the subject being assessed, but typically it lasts three to five minutes. A modified sequence of movements are used in which changes in body posture are minimised.²³

According to the scale of measurement and the way the evaluation maps were designed, data follow Gaussian distribution centring on score 2, with scores 1 and 3 less common and the extreme scores, 0 and 4, quite rare. So it is valid to add together the results of each of the 20 movements to obtain an overall flexibility or joint mobility index, called the Flexindex, which is a major advantage over other methods such as goniometry, where this is not possible.

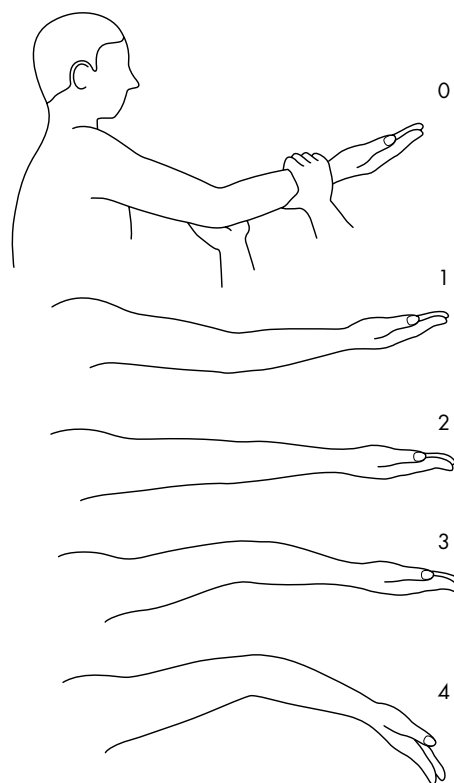
For the Flexindex, the overall flexibility of an individual can be easily compared with his/her centile curves for age and sex. The Flexitest curves for centiles 3, 10, 25, 40, 60, 75, 90, and 97, per age group and sex were generated based on over 3100 subjects.²³ Owing to the Gaussian nature of the scales for each movement and the global scale, it is possible to study the entire mobility range, as the maximum extreme values (0 and 80 points) are never actually obtained. Therefore there are not the so-called ceiling and floor effects often seen with other mobility tests. Because of the wide age range of our subjects, we analysed the Flexindex in both absolute (sum of points) and relative (centile) terms.

In theory, the same Flexindex result may be originated from different combinations of results for each movement. For instance, a Flexindex of 40 may occur if all movements

Table 2 Kinesiological description of the 20 movements of the Flexitest

Movement number	Kinesiological description
I	Ankle dorsiflexion
II	Ankle plantar flexion
III	Knee flexion
IV	Knee extension
V	Hip flexion
VI	Hip extension
VII	Hip adduction
VIII	Hip abduction
IX	Trunk flexion
X	Trunk extension
XI	Trunk lateral flexion
XII	Wrist flexion
XIII	Wrist extension
XIV	Elbow flexion
XV	Elbow extension
XVI	Shoulder posterior adduction at 180° of abduction
XVII	Shoulder extension and posterior adduction
XVIII	Shoulder posterior extension
XIX	Shoulder lateral rotation at 90° of abduction*
XX	Shoulder medial rotation at 90° of abduction*

*At 90° elbow flexion.

**Figure 1** Flexitest movement number XV (elbow extension).

are rated 2, or if 10 movements are rated 1 and the other 10 are rated 3. Although the Flexindex is the same in both instances, the passive joint mobility profiles are quite different. Therefore assessment of overall flexibility should consider not only the Flexindex, but also the profile of range of motions of individual movements. The profile of flexibility measurement homogeneity for a subject was assessed using five indices specifically calculated for this purpose: (a) intermovement variability index (IMVI); (b) interjoint variability index (IJVI); (c) flexion-extension variability

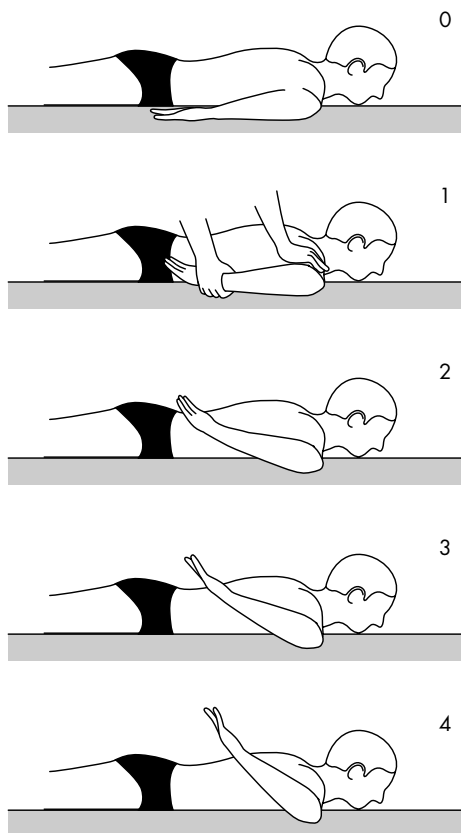


Figure 2 Flexitest movement number XX (shoulder medial rotation at 90° of abduction).

index (FEVI); (d) between segment variability index (BSVI); (e) distal-proximal variability index (DPVI). Interestingly, the first two indices, IMVI and IJVI, are not influenced by age, sex, or the magnitude of the Flexitest, which makes them very easy to be interpreted. Because of the way the other three indices are calculated, their values tend to be equal to 1. Particularly interesting is the DPVI, for which higher values are normally seen in older subjects, and lower values are typically seen in children and adolescents. A detailed explanation of the calculation and interpretation of these indices is available elsewhere.²⁶

Finally, the Flexitest measures range of motion in seven sets of joints (number of movements): ankle (two), knee (two), hip (four), trunk (three), wrist (two), elbow (two), and shoulder (five). Often, it is desirable to compare flexibility in different joints of the same subject; however, as we have a distinct number of movements per joint, the sum of each one's scores is not directly comparable. A simple mathematical strategy is to standardise the sums and transform them into adjusted scores, such as the Flexindex, by multiplying by 20 and then dividing by the number of movements for that specific joint set. For instance, for the ankle there are only two movements, thus the two scores are added together, multiplied by 20 (total number of movements), and the total is divided by 2 (number of movements for that joint). This final result is directly comparable with the Flexindex and with the adjusted scores of other joints.²³

Some simple hyperlaxity tests were also applied in our subjects during the clinical examination. Specifically, we tested elbow hyperextension, fifth finger hyperextensibility, and thumb apposition to the arm's ventral face on the right side of the body and extreme wide cubital angle (also known as carrying angle) as indicated by being able to join the

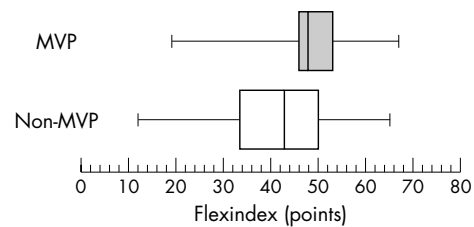


Figure 3 Absolute Flexindex values for women with and without mitral valve prolapse (MVP).

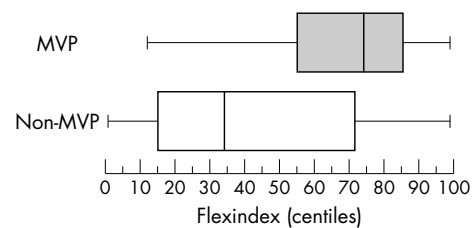


Figure 4 Relative (centile) Flexindex values for women with and without mitral valve prolapse (MVP).

elbows with both arms fully extended. Some of these hyperlaxity tests were extracted from the Beighton-Horan testing protocol.²⁵

Statistical analyses were performed by *t* test for interval data (including the Flexindex) and by the χ^2 test for ordinal or nominal data. Because of the theoretical assumption that there would be a difference, a one tail statistical approach was chosen. A 5% level of probability was used for statistical significance. Before data collection, all subjects signed an informed consent form which was previously approved by the institution. The same doctor carried out all the procedures included in the evaluation protocol.

RESULTS

Women with MVP were marginally taller and lighter and therefore had significantly lower body mass index scores. Heath-Carter anthropometric somatotype also clearly differed between women with and without MVP, with the former being less endomorphic and mesomorphic but considerably more linear. Ease of sitting on and rising from the floor (sitting and rising test) was significantly greater for women with MVP ($p < 0.01$). Cardiac vagal tone and presence of cardiac arrhythmias in electrocardiographic recordings, both at rest and exercise (4 second exercise testing and maximal cardiopulmonary exercise testing), were similar for women with and without MVP ($p > 0.05$). On the other hand, mild systolic murmurs at cardiac auscultation were at least three times more common in the women with MVP: 61% *v* 18% ($p < 0.01$).

Moving to our main focus, flexibility data, mean Flexindex absolute results (48 (1.6) *v* 41 (1.3) points (mean (SEM)); median results 48 *v* 43; $p < 0.01$) showed that women with MVP were about 15% more flexible on average than those without (fig 3). None of the adult women studied exhibited generalised hypermobility—that is, a Flexindex score of over 70 points—although scores exceeding 55 points were at least three times more common in women with MVP. On analysis of Flexindex centile data according to age and sex norms, women with MVP were placed at considerably higher levels than those without MVP: mean centiles 67 *v* 42 ($p = 0.005$). Over 22% and 77% of women with MVP obtained Flexindex results that respectively exceeded centiles 90 and 75,

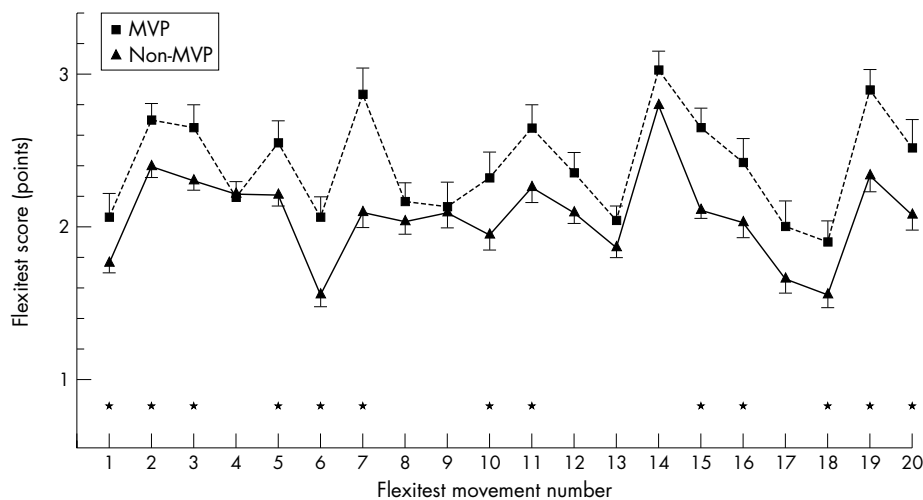


Figure 5 Flexitest individual movement scores for women with and without mitral valve prolapse (MVP). *Significantly different ($p < 0.05$).

contrasting with 8% and 32% of those without MVP ($p < 0.01$) (fig 4).

Flexibility evaluation revealed a tendency for higher values in the standardised joint scores for women with MVP; however, differences were of borderline significance for knee ($p = 0.071$), trunk ($p = 0.067$), and range of motion in the wrist ($p = 0.044$), and clearly significant for ankle ($p = 0.01$), elbow ($p < 0.01$), and shoulder ($p = 0.01$) movements.

As for individual movements assessed with the Flexitest, again there was a clear tendency toward higher values in the affected women, reaching statistical significance in 13 of the 20 movements (fig 5). Interestingly, movements typically used in some other flexibility evaluation protocols, such as knee extension, which is used to test hyperextension in the Beighton-Horan method, and trunk flexion, which resembles the sit and reach test, did not show significant differences. For trunk flexion, most of the subjects in both groups scored a 2, and the mean values were practically identical (2.13 and 2.09 respectively for the women with and without MVP).

On the other hand, for elbow extension, there was a clear difference between the two groups: 2.65 (0.12) and 2.11 (0.07) ($p < 0.001$) respectively for women with and without MVP. Moreover, scores of 0 or 1 for this movement were not found in women with MVP, but were found in at least 10% of women who did not have MVP, defining high specificity. Another movement for which the absence of scores of 0 or 1 reveals high discriminative power is shoulder lateral rotation, with 0% v 20% prevalence in the women with and without MVP respectively.

Scoring a 4 in the Flexitest was at least twice as common in the women with MVP, but it also occurred in at least 5% of the movements of unaffected women. The prevalence of at least three scores of 4 from among those for the 20 movements was 25% and 10% respectively for the subjects with and without MVP.

When considering the five Flexitest variability indices, only DPVI tended to differ between the two groups. Women with MVP had slightly lower DPVI: 1.11 (0.1) v 1.49 (0.2) ($p = 0.08$).

There was a striking difference between the two groups of women with regard to the hyperlaxity tests: the women with MVP were almost five times more likely to show signs of hyperlaxity than the rest (74% v 16%). Except in a single case, a lady of 73, the women with MVP but without signs of hyperlaxity had a Flexindex centile ≥ 65 .

DISCUSSION

Our study presents some features and unique characteristics that require comment. Ideally, the diagnosis of MVP should be carefully documented using rigid clinical and echocardiographic criteria. In our sample, we had to rely primarily on the reported medical history, as in only a few cases was an echocardiogram available for review. Although this could be thought a limitation, it tends to minimise the chance of finding significant differences—because all subjects classified as MVP either supplied this information spontaneously or we were able to retrieve it from their medical records or echocardiograms, whereas there was a real likelihood that some of those classified as non-MVP in reality had this condition but were misclassified. On the other hand, a retrospective approach, a large and unselected sample, a single evaluator for all subjects, and the use of a more comprehensive evaluation protocol, especially for flexibility assessment, represent both original and methodological positive aspects of our study. The relatively high prevalence of MVP in our sample (about 25%) may be explained by the tertiary characteristics of our medical services. Timing of the menstrual cycle was not taken into account as it does not seem to significantly affect Flexitest results.²⁷

Adult women with MVP would appear to have a unique physical and clinical profile. Certain anthropometric data were quite different between women with and without MVP, but the most striking differences were found in joint

What is already known on this topic

Collagen tissue disorders that affect joint range of motion and mitral leaflet excursion may have a common biochemical and histological basis, making women with mitral valve prolapse more flexible than the general population

What this study adds

Adult women with mitral valve prolapse often show signs of hyperlaxity and have a high Flexindex score, both in absolute and relative (centile) terms, whereas hypomobility in elbow extension and shoulder medial rotation seem to exclude this possibility

mobility. Most of the women with MVP had signs of hyperlaxity and a high Flexindex score, both in absolute and centile terms. These results obtained using a more comprehensive flexibility evaluation protocol than usual agreed with most data in the literature.^{9 11 15 17} Although there was a clear tendency to higher overall and specific flexibility in the women with MVP, it was not always possible to identify them exclusively on the basis of joint mobility evaluation. The presence of great or relative hypomobility in elbow extension and shoulder medial rotation—that is, scores of 0 or 1 in the Flexitest—seemed to exclude the possibility of MVP in our subjects. On the other hand, Flexitest scores of 4 in three or more movements was more often seen in the women with MVP. It is worth noting that trunk flexion, typically assessed with the sit and reach test, had the least discriminatory power in identifying the presence of MVP in the subjects. According to our data, Flexindex centile scores lower than 65 and the absence of signs of hyperlaxity should be very rare or non-existent in adult women younger than 65 with MVP, providing a kinanthropometric criterion for the clinical exclusion of this feature.

In conclusion, the Flexitest, whether by the use of two of its movements or the whole set of 20, alone or in combination with hyperlaxity tests, may be useful in the physical examination and clinical assessment of adult women with MVP. Further research is needed to identify potential applications of these results for different ethnic groups, young women, and specific arts and sports groups.

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Competing interests: none declared

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