

Speckle tracking for left ventricle performance in young athletes with bicuspid aortic valve and mild aortic regurgitation

Laura Stefani^{1*}, Alessio De Luca¹, Nicola Maffulli², Roberto Mercuri¹, Gabriele Innocenti¹, Irina Suliman¹, Loira Toncelli¹, Maria Concetta Vono¹, Brunello Cappelli¹, Stefano Pedri³, Gianni Pedrizzetti⁴, and Giorgio Galanti¹

¹Non-invasive Cardiac Laboratory, Department of Sports Medicine Centre, University of Florence, Florence, Italy;

²Department of Trauma and Orthopaedic Surgery, Keele University School of Medicine, Stoke-on-Trent, UK; ³ESAOTE, Florence, Italy; and ⁴Department of Civil and Environmental Engineering, University of Trieste, Trieste, Italy

Received 28 August 2008; accepted after revision 21 December 2008; online publish-ahead-of-print 27 January 2009

KEYWORDS

BAV;
Athletes;
Strain

Aims Longitudinal peak systolic strain (LPSS) quantifies regional and global heart function. Few data are available on left ventricle (LV) performance in young athletes with bicuspid aortic valve (BAV), where a pattern of mild aortic insufficiency is relatively frequent, and the ejection fraction (EF) is often normal for a long time. We report the measurement of LV strain in young BAV athletes.

Methods and results Three groups (20 athletes with BAV, 20 healthy athletes, and 20 sedentary healthy subjects, all aged 25 ± 3 years) underwent standard echo examination to evaluate LPSS at the basal and medium-apical segments of the lateral wall (LW) and interventricular septum (IVS) of the LV. LPSS was within the normal range; however, in BAV athletes, the LPSS of the basal segments tended to be lower ($S\%IVS_{\text{basal}}, -17.7 \pm 2.7$; $S\%LW_{\text{basal}}, -14.2 \pm 2.2$; $S\%IVS_{\text{med-apic}}, -21 \pm 3.5$; $S\%LW_{\text{med-apic}}, -18.8 \pm 4.2$), producing a gradient from basal to apical regions. The EF was normal in all subjects.

Conclusion Young trained BAV athletes have normal LV performance. Nevertheless, these athletes tend to have lower strain than healthy subjects in the LV basal segments. The clinical implications of this finding are uncertain and require further investigation.

Introduction

Strain (S), and particularly longitudinal peak systolic strain (LPSS), is a method for quantifying global and regional myocardial function.^{1,2} Strain is currently measured by two methods: tissue Doppler imaging and speckle tracking (ST). LPSS evaluation using ST has recently been used to investigate left ventricle (LV) systolic function in order to identify any modifications in subjects with pathological myocardial hypertrophy and normal systolic function.³ In athletes, LPSS can be used to study the behaviour of the LV segments.⁴

Longitudinal peak systolic strain plays a particularly important predictive role in the initial LV dysfunction of heart valve diseases such as aortic regurgitation or stenosis.^{5,6} There is some evidence that, despite a normal ejection fraction (EF), S in the LV may be reduced in subjects with aortic valve lesions,⁷ and these lower values

have been used as an indication for early surgery in such patients.

Bicuspid aortic valve (BAV) is one of the most common congenital cardiac diseases, both in the general population and in athletes,⁸ and when the aortic valve incompetence is mild and the EF is preserved, it is not an obstacle to regular sporting activity. However, a recent 5-year follow-up study⁹ has demonstrated that in BAV athletes there is a significant yearly progressive increase in LV dimensions when compared with tricuspid aortic valve (TAV) athletes, although the values are maintained within the normal range, as are also those of the EF. We hypothesized that LPSS might play a role in proving the existence of normal LV function in athletes with BAV in whom the EF is still normal.

The present study evaluated LPSS in athletes with BAV and aortic valve insufficiency when compared with healthy athletes with normal TAV and a healthy sedentary group.

* Corresponding author. Tel: +39 0329 420 4277; fax: +39 055 7949375.
E-mail address: laura.stefani@unifi.it

Methods

We examined a group of 20 male athletes (15 soccer and 5 basketball players, aged 25.4 ± 1 years) with BAV and mild aortic regurgitation. They were age- and sex-matched with 20 athletes (14 soccer and 6 rugby players) with TAV who were following a similar training programme to healthy athletes. The enrolled athletes were trained in different types of endurance sports and they can thus be considered comparable regarding the effects of the physical exercise on the heart. Twenty age- and sex-matched sedentary healthy subjects were enrolled as a control group. All athletes, followed yearly at our Sport Medicine Centre during the regular Pre-Participation Screening, generally trained 2 h per session three times a week for at least 10 months a year for almost 4 years (Table 1). This training programme, which was homogeneous for all the athletes enrolled, conformed to a programme commonly followed by athletes within the same age range. In the BAV group alone, four subjects had been practising the sporting activity for only 3 years. The other 16 athletes had been following a regular training schedule for almost 4 years. Following the American Heart Association Guidelines,¹⁰ a complete traditional echocardiogram using My Lab 30 (Esaote, Florence, Italy) echocardiograph equipped with 2.5 MHz probe was performed in each subject at rest. The following were calculated: basal 2D systo-diastolic and Doppler parameters, interventricular septum (IVS), posterior wall thickness, left ventricular end-diastolic diameter, left ventricular end-systolic diameter, left atria dimension, aortic root (Aor) dimension, peak velocities of pulsed wave Doppler transmitral flow during early diastole (E) and atrial systole (A), deceleration time of early diastolic flow, and isovolumic relaxation time. The evaluation of left ventricular cardiac mass index (g/m^2) was obtained using the Devereux procedure,¹¹ and the EF (%) was calculated by the Simpson rule method.

The degree of severity of the valvular insufficiency, described as the extent of the regurgitant jet on a 0 to 4+ scale, was assessed using the colour-flow mapping method from the four-chamber view, according to the ACC/AHA Guidelines.¹⁰

From the four-chamber view, using X-Strain software included in the My Lab 30 echo (Esaote, Italy), the LPSS at the basal and mid-apical segments of the lateral wall (LW) of LV and the IVS was calculated in all the subjects.

Our Ethics Committee approved all the procedures described in the present study, and all the subjects gave their written informed consent to participate.

Strain analysis by speckle tracking model

The 2D images of four-chamber views were post-processed with X-Strain software to provide an angle-independent tool for the evaluation of velocities and strain. This software allows automatic evaluation of the dynamic properties of the endocardial border and of the sub-endocardial tissue from 2D B-mode echocardiographic clips. Strain analysis by ST is independent of translational motion, tethering effects of the nearby regions, and it thus allows uniformity of measurements through the normal LV myocardium. The endocardial border is drawn by the operator in a four-chamber view on a single frame from one annulus to another; the first and last points delineate the mitral plane. The LPSS was measured in basal and mid-apical segments of the LW and IVS from the images captured at rest (Figure 1).

Statistical analysis

All data are reported as mean \pm SD. The comparisons between LPSS values of basal and mid-apical segments for each group were performed using Student's unpaired *t*-test, using SPSS 13. A probability value (*P*) of <0.05 was considered statistically significant. One-way analysis of variance was used for multivariate comparison of aortic size and LV parameters within the BAV, TAV, and control groups (Figure 2).

Table 1 Characteristics of bicuspid aortic valve athletes, tricuspid aortic valve athletes, and controls

	BAV athletes	TAV athletes	Controls	<i>P</i>
General data				
Age (years)	25.4 ± 1	26 ± 1	24.4 ± 1	NS
SBP (mmHg)	111 ± 3	113 ± 4	116 ± 5	NS
DBP (mmHg)	80 ± 2	78 ± 3	74 ± 2	NS
BSA (m^2)	1.9 ± 0.3	2.1 ± 0.13	1.8 ± 0.4	NS
Echocardiographic data				
LAD (mm)	33 ± 4	35 ± 3.5	31.9 ± 4.4	NS
IVS (mm)	9.28 ± 1.1	9.2 ± 0.9	8.9 ± 1.1	NS
PWT (mm)	9.1 ± 0.7	9.1 ± 0.8	8.8 ± 1.2	NS
Aor (mm)	33.4 ± 4.2	30.9 ± 3.8	28.5 ± 3.2	$P < 0.0001^{**}$
RV (mm)	23 ± 3	22.5 ± 2.5	20.5 ± 2	NS
LVEDD (mm)	51 ± 3.2	52 ± 4.1	47 ± 4	$P < 0.05^*$
LVESD (mm)	32.8 ± 3.3	32.2 ± 2.5	28.4 ± 4	$P < 0.05^*$
DT (ms)	192.6 ± 42	194.4 ± 33	176.2 ± 35	NS
IVRT (ms)	77.8 ± 12	81.7 ± 13	72.2 ± 12	NS
E peak (m/s)	94 ± 12	83.4 ± 15	89.5 ± 13	NS
A peak (m/s)	50.6 ± 11	52.4 ± 10	56 ± 10	NS
CMI (g/m^2)	116 ± 3.3	115 ± 7.2	94 ± 2.4	$P < 0.05^*$
EF (%)	65.4 ± 3	64.7 ± 4.7	65.8 ± 5	NS

BAV, bicuspid aortic valve; TAV, tricuspid aortic valve; SBP, systolic blood pressure; DBP, diastolic blood pressure; BSA, body surface area; LAD, left atria dimension; IVS, interventricular septum; PWT, posterior wall thickness; Aor, aortic root dimension; RV, right ventricle; LVEDD, left ventricular end-diastolic dimension; LVESD, left ventricular end-systolic dimension; DT, deceleration time; IVRT, isovolumic relaxation time; E peak, E (velocity) peak; A peak, A (velocity) peak; CMI, cardiac mass index; EF, ejection fraction.

^{**}Significant difference between BAV, TAV, and control groups.

^{*}Significant difference between BAV and TAV group compared with control.

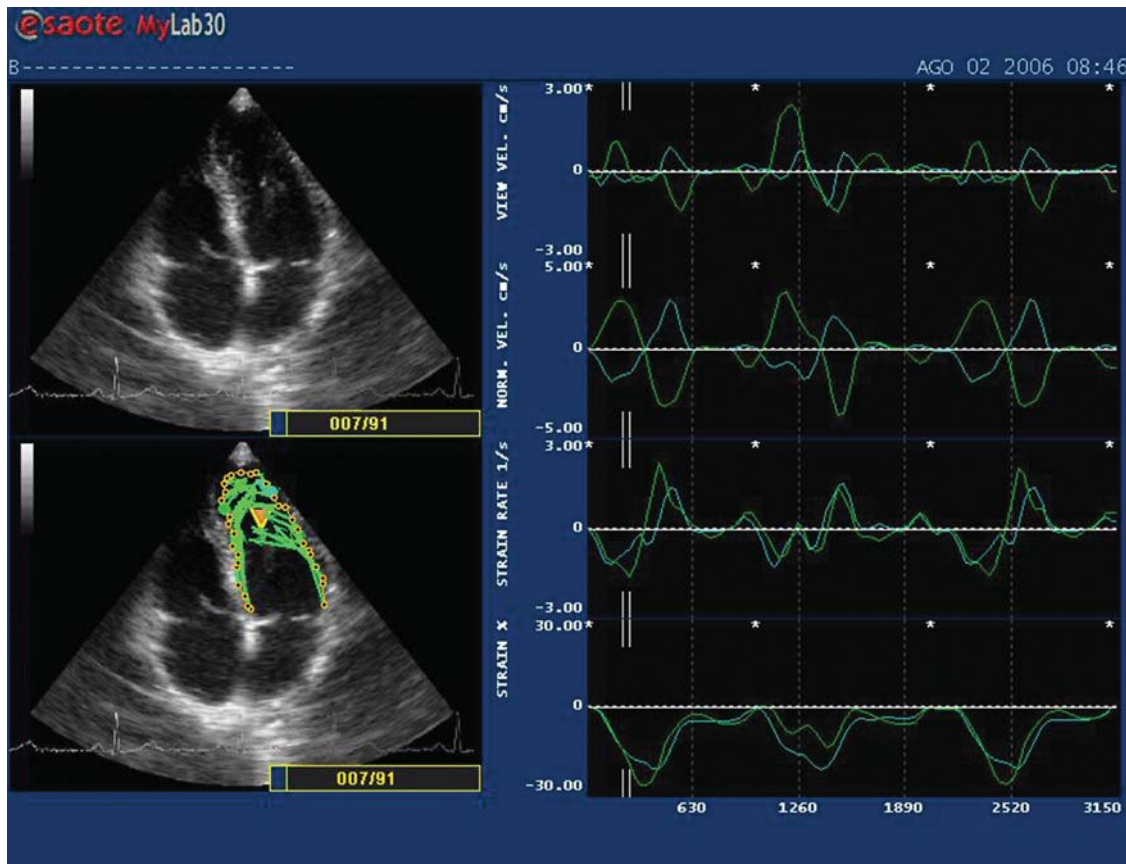


Figure 1 Assessment of strain in the left ventricle using the X-Strain programme. Starting from this image, it is possible to obtain the longitudinal peak systolic strain value in every segment of the left ventricular myocardial walls.

Results

The three groups showed no significant differences for age, systolic blood pressure, diastolic blood pressure, and body surface area (Table 1).

Regarding the echocardiographic parameters, no statistical differences were found among the groups studied, the results of the BAV and TAV athletes being comparable. In the control group, however, all the LV values tended to be slightly lower when compared with the athletes (Table 1).

Cardiac mass index was greater in both groups of athletes ($P < 0.05$). As expected, the Aor diameter in athletes with BAV was significantly greater than in athletes with TAV and in controls. The valvular insufficiency present in all the BAV athletes was mild according to the AHA Guidelines.¹⁰ None of the BAV subjects in the present study showed aortic stenosis at echocardiography. All subjects studied had normal LPSS values. However, the LPSS analysis for each group showed similar values in TAV athletes and control groups. In athletes with BAV, LPSS was at the lower extremes of normality and produced a marked gradient from the basal to the mid-apical segments, which was not evident in TAV athletes and controls (Table 2).

Discussion

In the general population, in the presence of valvular heart disease strain is considered a useful marker to study before and after removal of the damage induced by the valvular

dysfunction.^{5,6} In athletes where myocardial hypertrophy is a physiological and adaptive response to regular exercise,¹² EF by itself might not be enough to evaluate overall LV performance, and strain could be used as a tool to investigate myocardial performance.

In athletes with BAV, the clinical manifestations of onset are usually mild or absent. Subjects are normally asymptomatic and LV performance is preserved, so sporting activity is commonly allowed¹³ in BAV with mild stenosis or aortic regurgitation, with prescription of a periodic examination.¹⁴ Although BAV has usually been considered as a disease with predominant involvement of the aortic tract, more recently several authors have hypothesized that the contractile property of the entire surface of heart myocardial walls is affected.^{15,16} The possible influence of regular sporting activity on this aspect has not yet completely been investigated,⁹ with the exclusion of the sudden cardiac death risk in moderate/severe BAV athletes that participate in competitive sport.^{17,18}

Our results show that in athletes with BAV the LPSS values tend to be near the lower limits of the normal and validated range. This trend of strain in BAV, not present in the control groups studied, becomes significant only if we consider the differences in the strain values of the basal, when compared with the apical, segments of the LV. Despite this, the intimate mechanism of these particular strain data in BAV athletes is not yet well explained by the results obtained in this session, and more investigations, with a yearly follow-up, will be necessary in future to compare the behaviour of strain in different groups of athletes.

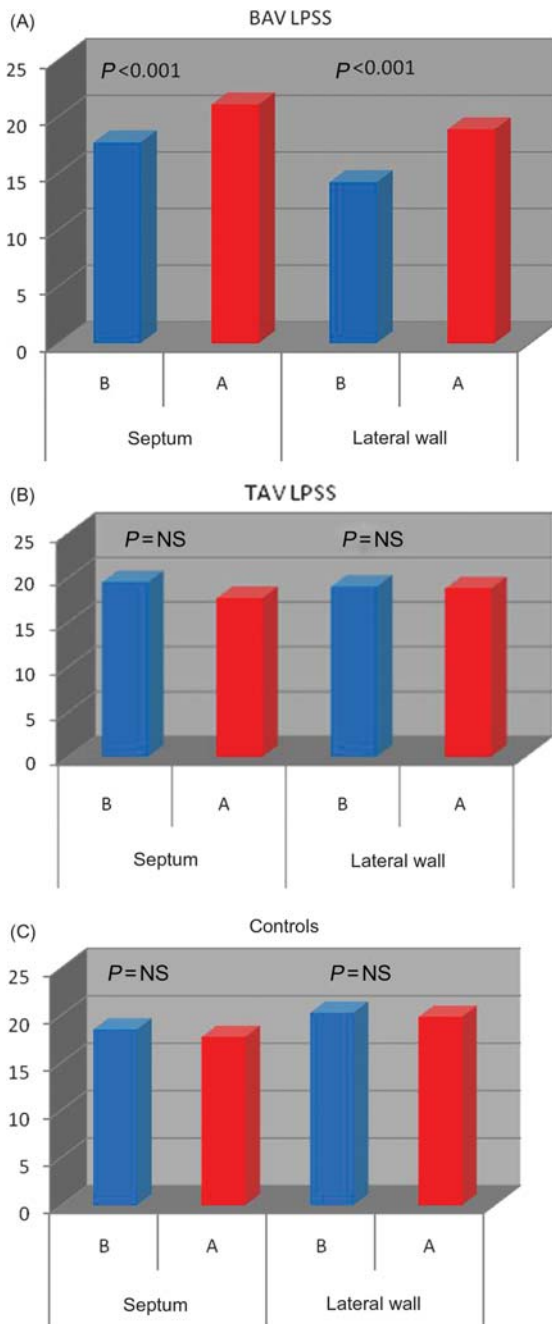


Figure 2 (A–C) Longitudinal peak systolic strain (LPSS) of the basal and mid-apical segments of the left ventricle (LV) in bicuspid aortic valve (BAV), tricuspid aortic valve (TAV), and controls. The three graphs show the LPSS values of the basal (B) and mid-apical (A) segments of the interventricular septum and LV lateral wall in BAV, TAV, and controls, respectively. The negative sign was omitted; therefore, the strain values presented resulted positive. All the results are within the normal range.

Starting from our previous study on a group of BAV-trained athletes,⁹ where a significant yearly increase in heart dimensions was demonstrated although it remained within the normal range of values, this particular behaviour of LV strain could be considered a helpful tool for completing the evaluation and for confirming the normal LV myocardial performance. Bearing in mind that strain is a contractility parameter, the reduction in strain values could be considered as a helpful aid for guiding athletes with BAV towards abstention from high-intensity sport in the case of a decrease in LV performance which is not yet evident from the standard echo parameters. However, considering that no significant differences in LV strain were found among the groups analysed, regular sports training alone does not seem to have any evident negative effect on the heart.

We acknowledge that we studied relatively small cohorts, but these were substantially homogeneous as regards the intensity of the sporting activity; in fact, only four BAV athletes had been training regularly for a period of <3 years. However, the clinical implications of the strain value in the basal LV segment in athletes with BAV, which is lower than in TAV athletes, are not yet clear, and more investigations will be necessary to better clarify this behaviour of the deformation parameters in BAV.

In our opinion, it is not yet possible to clarify whether the strain decrease might precede the reduction in the LV function, and more data have to be obtained from other athlete populations, also including subjects affected with other types of cardiomyopathy. In addition, to ascertain whether strain reduction can be influenced by the degree of the aortic valve regurgitation or stenosis, more information will need to be gleaned from the analysis of a group of athletes with TAV and mild regurgitation or stenosis, not investigated in this study.

Nevertheless, considering the relatively young age of the group studied, and despite the fact that the follow-up study was performed for quite a long period, even up to 4 years, the decision to continue submitting BAV athletes to a periodic examination seems to be crucial.

Conclusions

This study investigates the role of LPSS in addition to the standard 2D-echo measurements in athletes with BAV, confirming the normal LV performance in these athletes. Although these are preliminary results in a relatively small group, they do suggest the possibility of adding strain evaluation to the study of LV performance in athletes with BAV, which has traditionally been evaluated exclusively in terms of the aortic tract. LPSS can be used as a tool for a more complete cardiac evaluation in trained athletes, even if no further information is currently available from strain

Table 2 Strain analysis results

LPSS %	IVS _{basal}	IVS _{med-apic}	P	LW _{basal}	LW _{med-apic}	P
BAV _{Athletes}	-17.7 ± 2.7	-21 ± 3.5	0.001	-14.2 ± 2.2	-18.8 ± 4.2	0.001
TAV _{Athletes}	-19.5 ± 5.9	-17.71 ± 3.8	NS	-19.05 ± 4.0	-18.80 ± 3.80	NS
Controls	-18.5 ± 4.8	-17.7 ± 3.96	NS	-20.28 ± 2.9	-19.82 ± 4.7	NS

BAV, bicuspid aortic valve; TAV, tricuspid aortic valve; IVS, interventricular septum; LW, lateral wall; LPSS, longitudinal peak systolic strain.

analysis for differentiating the physiological LV hypertrophy due to regular training from the pathological form. The evaluation of the radial and circumferential components of strain in LV in BAV athletes might be useful in future for better identifying strain performance in this particular group, and also for clarifying the clinical significance of our results. The strain measurements could also usefully be extended to athletes who have stopped their sporting activity due to the progression of valvular incompetence, as well as to those subjects with BAV who have undergone surgical aortic valve replacement.

Acknowledgements

We thank Susan Charlton, language assistant at the University of Florence, for her English language revision.

Conflict of interest: none declared.

References

1. Stig U, Thor E, Hans T, Bjorn A, Otto AS. Myocardial strain by Doppler echocardiography. Validation of a new method to quantify regional myocardial function. *Circulation* 2000;**102**:1158–64.
2. Souterland GR, Di Salvo G, Claus P, D'Hooghe J, Bijmens B. Strain and strain rate imaging: a new clinical approach to quantifying regional myocardial function. *J Am Soc Echocardiogr* 2004;**17**:788–802.
3. Serri K, Reant P, Lafitte M, Berhouet M, Le Bouffos V, Roudant R *et al.* Global and regional myocardial function quantification by two dimensional strain. Application in hypertrophic cardiomyopathy. *J Am Coll Cardiol* 2006;**21**:1175–81.
4. Stefani L, Toncelli L, Di Tante V, Cappelli B, Pedrizzetti G, Galanti G. Supernormal functional reserve of apical segments in elite soccer players: an ultrasound speckle tracking handgrip stress study. *Cardiovasc Ultrasound* 2008;**16**:6–14.
5. Onishi T, Kawai H, Furukawa M, Okada M, Noroisada K, Tatsumi K. Prognostic importance of myocardial peak systolic strain rate in asymptomatic patients with chronic aortic regurgitation. *Eur J Echocardiogr* 2007;**8**:S141.
6. Faber L, Muntean BG, Butz T, Welge D, Hering D, Horskotte D. Regional peak systolic strain assessed by 2D strain analysis (2DS) in patients with aortic valve stenosis (AS) and obstructive hypertrophic cardiomyopathy (HOCM). *Eur J Echocardiogr* 2007;**8**:S138.
7. Poulsen SH, Segard P, Nielse-Kudsk JE, Egeblad H. Recovery of left ventricular systolic longitudinal strain after valve replacement in aortic stenosis and relation to natriuretic peptides. *J Am Soc Echocardiogr* 2007;**20**:877–84.
8. Stefani L, Galanti G, Toncelli L, Manetti P, Vono MCR, Rizzo M. Bicuspid Aortic Valve in competitive athletes. *Br J Sports Med* 2008;**42**:31–5.
9. Galanti G, Stefani L, Toncelli L, Vono MCR, Mercuri R, Maffulli N. Effects of sport activity in athletes with bicuspid aortic valve and mild regurgitation. *Br J Sports Med* 2008 (Jun 3 pub. online).
10. Cheitlin MD, Armstrong WF, Aurigemma GR. ACC/AHA/ASE 2003. Guideline update for the clinical application of echocardiography: a report of the American College of Cardiology, American Heart Association task force on practice guidelines. *J Am Soc Echocardiogr* 2003;**10**:1091–110.
11. Devereux RB. Detection of left ventricular hypertrophy by M-mode echocardiography. Anatomic validation, standardization and comparison to other methods. *Hypertension* 1987;**20**:1251–60.
12. Calderón Montero FJ, Benito Peinado PJ, Di Salvo V, Pigozzi F, Maffulli N. Cardiac adaptation to training and decreased training loads in endurance athletes: a systematic review. *Br Med Bull* 2007;**84**:25–35.
13. Pelliccia A, Fagard R, Bjørnstad HH, Anastassakis A, Arbustini E, Assanelli D *et al.*, Study Group of Sports Cardiology of the Working Group of Cardiac Rehabilitation Exercise Physiology; Working Group of Myocardial, Pericardial Diseases of the European Society of Cardiology. Recommendations for competitive sports participation in athletes with cardiovascular disease: a consensus document from the Study Group of Sports Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. *Eur Heart J* 2005;**26**:1422–45.
14. De Mozzi P, Longo UG, Galanti G, Maffulli N. Bicuspid aortic valve: a literature review and its impact on sport activity. *Br Med Bull* 2008;**85**:63–85.
15. Fedak PWM, de Sa MPL, Verna S. Vascular matrix remodelling in patients with bicuspid aortic valve malformation: implication for aortic dilatation. *J Thorac Cardiovasc Surg* 2003;**126**:797–806.
16. Le Marie SA, Wang X, Wilks JA. Matrix metalloproteinases in ascending aortic aneurysm bicuspid versus trileaflet aortic valves. *J Surg Res* 2005;**123**:40–8.
17. Corrado D, Pelliccia A, Bjørnstad HH, Vanhees L, Biffi A, Borjesson M *et al.* Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol. Consensus Statement of the Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. *Eur Heart J* 2005;**26**:516–24.
18. Thompson PD, Franklin BA, Balady GJ, Blair SN, Corrado D, Estes NA *et al.* Exercise and Acute Cardiovascular Events: Placing the Risks Into Perspective: A Scientific Statement From the American Heart Association Council on Nutrition, Physical Activity, and Metabolism and the Council on Clinical Cardiology Exercise and Acute Cardiovascular Events. *Circulation* 2007;**115**:2358–68.