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Research Article

A Successful Harmonious Development by Sport of a Child with Down Syndrome: Fifteen Years of Sport Medical Follow-Up

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Abstract

Background: Children with Down syndrome have long been banned from competitive sport practice. However in recent years, some clubs have emerged, helping children and youths with mental disabilities to improve health and well-being by regularly training them. To determine the effects of regular sports training, we followed a young man with Down syndrome, who had consistent swimming and cross-country skiing trainings at high level for 15 years.

Objective: This study is based on a multidisciplinary follow-up. During childhood, the follow-up of this young athlete of 14 years old was based on regular evaluations by the genetic department. Then when the sports training began, this athlete was followed by the sport medicine department according to the recommendations prescribed by the law concerning high-level sport.

Methods: During this study, every two years at least, one maximal effort test with cardiovascular follow-up was realized.

Results: The results obtained showed that regular physical activity contributed to the development of an excellent physical fitness and limited the overweight development which is frequently found in the Down syndrome. Cardiovascular and orthopaedic

monitoring of this young athlete proved to be regularly indispensable in the management of the health problems characteristic of this genetic syndrome.

Conclusion: Promoting physical activity guarantees the development of the children with Down syndrome. When sports trainings are well organized and accompanied by regular medical monitoring it demonstrates the ability of young child with Down syndrome to develop exceptional physical qualities.

Keywords: Sport medicine; Follow-up; Health; Down syndrome

1. Introduction

Nowadays, words such as sport, competition and performance are seen as essential values in our society and do not seem to fit with the idea of handicap, even more when it comes to intellectual disability. However, sport is gradually being opened up to these populations. In terms of health, the benefits of the physical activity (PA) have now been extended to these persons with special needs. Numerous studies have shown a lower aerobic capacity in subjects with Down syndrome (DS) compared to control subjects. The most commonly identified factors leading to the development of obesity and therefore lower aerobic capacity are a sedentary lifestyle, insufficient sports practice or limited access to physical activities, low motivation for any activity, and cognitive deficit. Moreover, Down syndrome is also associated with a whole range of endocrine disorders (hypo or hyperthyroidism, gonadal insufficiency, reduced growth hormone secretion and prevalence of diabetes). Abnormal endocrine secretions, which promote fat mass and lead to a change in body composition, can make it difficult to practice physical activities, mainly for physiological reasons, but also by reducing the pleasure and desire to practice.

People with overweight would then find themselves caught in a vicious circle and because of this excess weight and the need of energy required to move, would feel more comfortable living a sedentary life. By doing so, effort would be less tolerated by people with Down syndrome leading to harmful consequences on their overall health as well as their daily life by limiting their movements and therefore their autonomy, or even their integration into a professional environment. Numerous publications have confirmed the positive impact of PA programs on health, with a preventive role on obesity and motor skills improvement [1-8].

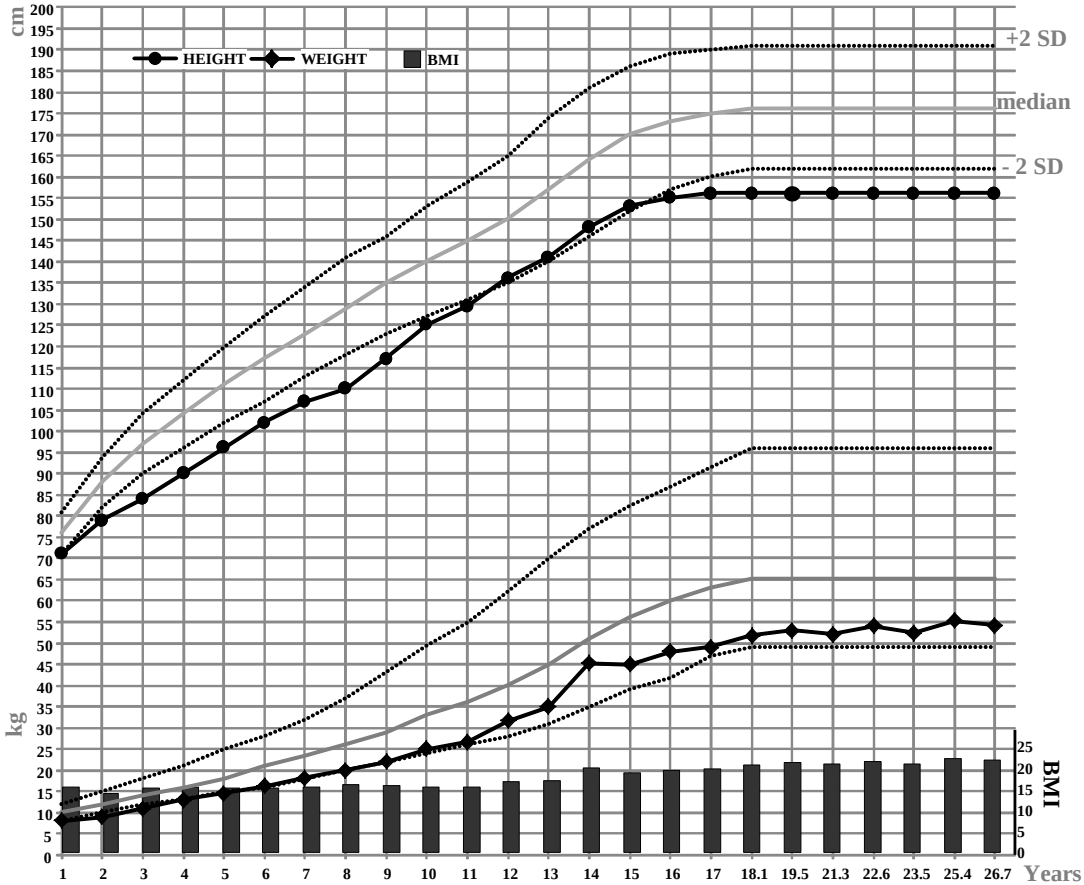
However, some questions remain: is a regular and intense PA possible for a young athlete with DS? Does it raise a specific problem of technical skills to be acquired for the DS practitioner? Is this PA not a source of excessive tiredness and finally, does it play a positive role for social inclusion? In order to answer these questions, this study presents the 15-years follow-up of a young man with DS, who regularly practiced a sport activity that enabled him, as an adult, to be in a very good fitness for a DS person, and be currently selected for the national adapted swimming team. As part of the monitoring of these athletes, the recommended tests in France are currently very well codified and framed by the biannual regulatory monitoring of high-level athletes (Law No. 99-223 of 23 March 1999 on the Health Protection of Athletes and the Control of Doping).

However, when monitoring a young athlete with DS, the various characteristic pathologies that are associated with this genetic syndrome [1-8], and therefore could limit sport activity, must be taken into account. The information gathered here should enable general practitioners caring for children with DS to better promote physical activity, for the benefit of the health of these young patients, while remaining vigilant about their characteristics.

2. Methods

We studied the case of a high-level male athlete under the care of the Sports Medicine Unit. The study was conducted in accordance with the principles established by the Declaration of Helsinki. The patient and his parents gave their written consent for this study, and by doing so, gave us the right to process their personal data.

XY (*for ethical and confidential reasons, code XY will be used to identify our patient*) is a young man with Down syndrome (47, XY, +21). He received clinical follow-up in hospital in two specialized departments: sports medicine and genetic. The results obtained come from this double follow-up. The anthropometric characteristics are presented in Figure 1, and the biological variables in Table 1.



BMI: body mass index=Weight/Height (m²); Height (cm); Weight (kg).

Figure 1: Growth monitoring of XY from 1 year to $26^{1/2}$.

3. Results

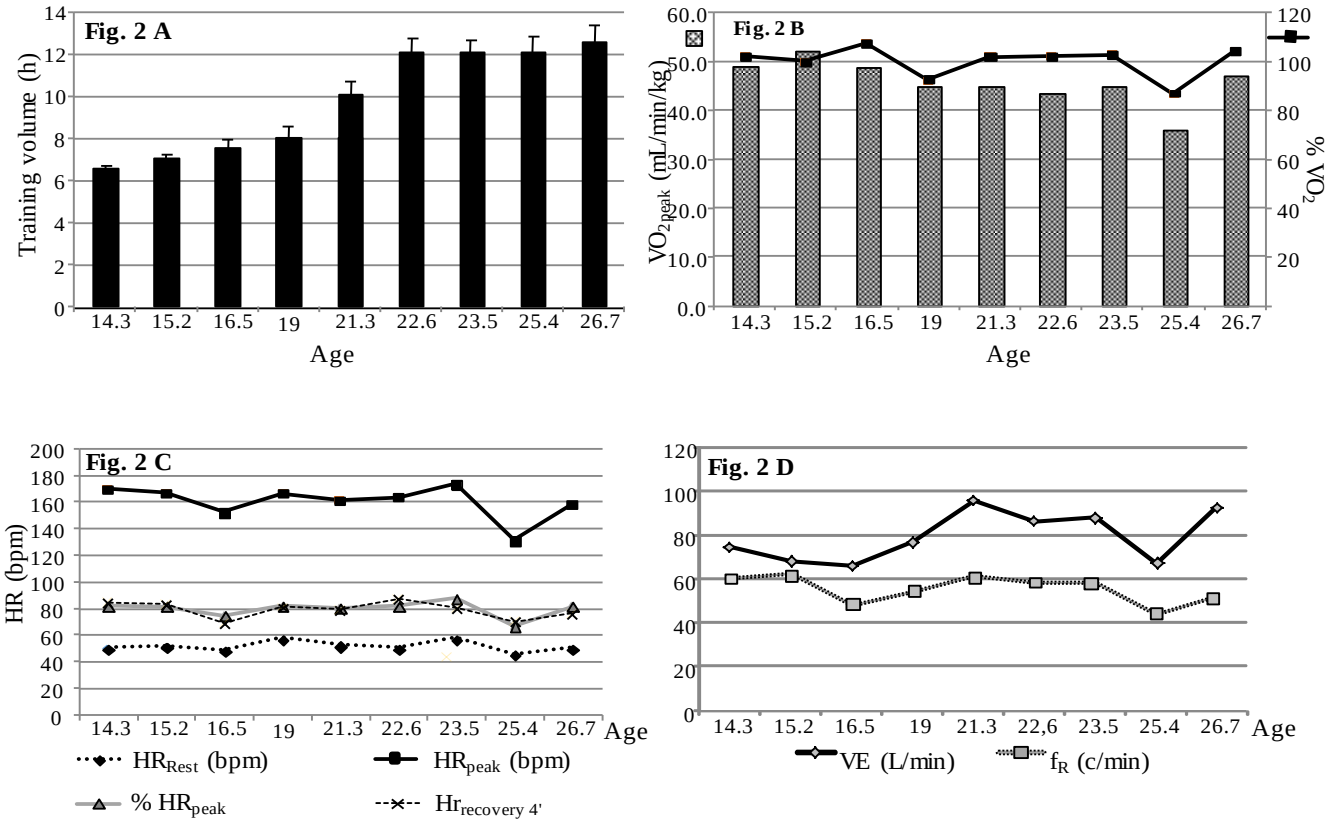
The first sport medicine consultation took place at the age of 14. Then, XY was regularly practicing several activities, and has begun to specialize himself in swimming and cross-country skiing. During winter ski sessions are organized followed by swimming and physical trainings during the summer (Figure 2A).

In adulthood, these sessions represent a total of 10 to 15 hours of sport per week. During the first check-up in the Sport Medicine Unit (at age 14), the clinical examination reported an excellent height-weight ratio (Figure 1; T=151 cm P=43.5 kgs; % fat mass: 14.7). Hyperlordosis, bilateral major valgus with collapse of the plantar arch and flat feet (3rd degree) were noted. The lower limbs were lax. Sinus bradycardia was observed at rest (48 bpm). The Sokolov index was a little high for a young adolescent of this age, and an echocardiographic/Doppler was programmed. A maximal treadmill exercise test (MTT) was performed on an ergometric bicycle. It provided a first reference value of the maximum aerobic capacity of this young athlete (Figure 2B; VO_2= 51.21 mL/min/kg; HR_{peak}=170bpm). From this date, XY benefited from the regulatory monitoring of high-level sportsmen. The following year (15.2 years old), no problem was reported, and the physical fitness was excellent, the echocardiographic/Doppler was normal.

At the age of 16 years$^{1/2}$, a new MTT was programmed following two post-exercise lipothymic syncopal episodes with pallor, sweating and severe tiredness. During the recovery of the MTT, vagal expression syncope was observed at the 4th minute. The electrocardiogram (ECG) examination was strictly normal with no conduction or repolarization disorder. The simultaneously programmed echocardiography was normal. At the same time, XY consulted for a left internal gonalgia, with functional pain when skiing.

These investigations concluded in favor of vagal syndrome, and also suggested, in view of the functional pains and the fatigue complaint, a possible overload of sport activities for this young athlete. It was proposed to reduce training in order not to cause osteo-articular overexertion. In 2010, XY turned 19 years old. A maximal treadmill test was scheduled. The results were good, with no complaint or pain. This examination revealed chronotropic incompetence, and a VO_{2peak} of 93% of the predicted values (Figure 2B). The ECG during MTT showed no rhythm or repolarization disorder, and the ventilatory adaptation was satisfying without the presence of tachypnea (Figure 2D). In 2012 (21.3 years), the maximal treadmill test showed an abnormal chronotropic response at its end (HR_{peak}=161 bpm vs. predicted HR_{max} =201 bpm; Figure 2C).

The following year (22 ans½) XY complained of bronchitis, difficulty of breathing during exertion, and vagal syncope during the World Ski Championships. A state of overtraining was suspected, especially as low back pain was also reported with a decrease in sport performance. The MTT performed this day remained nevertheless satisfactory, but there was still the same chronotropic incompetence. During practice, this state of fatigue leads to a decrease in training volumes, so that XY can rest before starting his swimming season.



2A: Training volume per week

2B: VO_{2peak} (ml/Kg/min) and predicted $\%VO_{2peak}$

2C: Heart rate (HR in beat per minute bpm); HR_{rest}, HR_{peak}, predicted % of HR_{peak} and $HR_{recovery}$ at the 4^{th} minute

2D: Ventilation (VE) and respiratory frequency (fR cycles per minute)

Figures 2 A à D: Follow-up of XY during 15 years.

At the beginning of the following winter season, XY (23.5 years old) returned for a check-up. He was coming back from an international competition in Mexico City, where he again had a post-effort vagal syncope (blurred vision, light-headedness). At the clinical examination, nothing particular was noted. The MTT result was satisfactory. Up to his 25 years[1/2], multiple vagal syncope episodes (while swimming and at rest) without abnormal fatigue were reported. The MTT was submaximal (VO_{2max} at 87% of theoretical value; HR_{peak} = 131bpm (67% of predicted HR ; Figures 2B-2C). It was decided to perform an orthostatic test to verify cardiovascular adaptations under autonomic control in response to stress. This test confirmed a bradycardia despite a good cardiovascular adaptation during the head-up tilt period, without sign of dysautonomia (no vagal discomfort, hypotension, postural tachycardia, nausea or sweating). No abnormalities were reported in a parallel biological examination (Table 1).

	9 years½	12 years	12 years ½	13 years	14 years	14 years ½	15 years ½	16 years	17 years
Cholesterol g/L	1.82						1.53		1.6
HDL g/L	0.48						0.55		0.49
LDL g/L	1.18						0.79		0.96
Cholesterol /HDL	3.79						2.78		3.27
Triglycerides g/L	0.82						0.96		0.76
Glycaemia g/L	0.71								
TSH mUI/L	2.9	2.79	1.82	2.28	2.15	1.21	2.15	1.22	2.39
Free T3 pmol/L	4.7	4.2	4.6	4.8	4.9	4.6	4.9	4.8	4.6
Free T4 pmol/L	16	17.1	17.8	12.6	19.1	16.2	19.1	14.2	16.2
IGF-1 ng/ml	219	287		304		342			353
Testosterone nmol/mol	0.2	1.2		19.4	16.3	11.3	16.3	13.3	30.3
DHEA-S mg/ml	3.5	4.1		3.6	4.8	6.8	4.8		
Ferritin mg/L	380								
Anti TPO UI/ml	15	15	15	14	9	12	9	12	1
Anti-TG UI/ml	15	15	15	14	15	15	15	16	7
	18 years	**19 years**	**19 years ½**	**21 years**	**22 years**	**23 years ½**	**24 years**	**25 years**	**26 years ½**
Cholesterol g/L	1.6	1.72		1.71	1.64	1.58	1.77	1.54	1.58
HDL g/L	0.49	0.53		0.56	0.5	0.51	0.52	0.54	0.51
LDL g/L	0.96	1.04		1.04	0.99	0.94	1.09	1.18	0.87
Cholesterol /HDL	3.27	3.25		3.05	3.28	3.10	3.40	2.85	3.10
Triglycerides g/L	0.76	0.76		0.53	0.73	0.68	0.81	0.7	0.99
Glycaemia g/L		0.76		0.83	0.9	0.97	0.92	0.87	NA
TSH mUI/L	1.45	3.08	2.67	1.31	1.21	0.581	2.94	1.61	1.53
Free T3 pmol/L	5.1		5.5					5.1	5.3
Free T4 pmol/L	17.6		12.2		11.3	13.7	13	14.7	16.9
IGF-1 ng/ml	338		321						
Ferritin mg/L						261	285		232
Anti TPO UI/ml	<60				<30	8	8	13	
Anti-TG UI/ml	<60				<20	18	17	12	

HDL: High-density lipoprotein, LDL: Low-density lipoprotein; TSH: thyroid-stimulating hormone; T3L: Free tri-iodothyronine; T4L: Free tetra-iodothyronine; IGF-1: insulin growth factor-1; DHEA-S: dehydroepiandrosterone sulfate; Anti TPO: anti-peroxidase antibody; Anti-TG : anti-thyroglobuline antibody.

Table 1: Biological variables.

Finally, a final MTT was programmed in 2018 (26 years[1/2]). The same chronotropic incompetence as previously observed was found. A few months later (27 years), during the preparation to the World Swimming Championships, XY returned for a consultation for fatigue with reduced performance. An ECG was carried out, but results came back perfectly normal. The training loads were adapted in volume and intensity, with a rest day added during the week.

4. Discussion

Sports competition has long been contraindicated for people with DS. Until the 1960s, literature concluded that competition was not suitable for populations with mental disabilities [9] because it resulted in aggressive [10, 11], regressive [12, 13] and chronic inability to adapt to the demands of the situation [14]. These so-called deviant behaviors justified the contraindication of the practice of sports for several decades. However, under the impetus of scientific work and various sports movements, a new current of thought has emerged. Nowadays, social demand is expressed by families and practitioners themselves, who are campaigning for a better access to sport. Our results illustrate these benefits of regular PA for people with Down syndrome, while carefully monitoring their own characteristics.

4.1 The classical morphotype of the DS (short stature, overweight/obesity)

Published studies on the medical follow-up of DS subjects confirmed a prevalence of 23 to 70% of overweight and obesity in this population [15-18] with body mass indexes all the more increased as the height is always lower than normal [19-21]. The contributing factors to this classical morphotype are based on a myriad of biological and environmental factors, such as:

- Endocrine pathologies such as hypothyroidism [16, 22, 23], growth hormone secretion abnormalities [2] and hyperleptinemia [24-26] all of which are clearly associated with weight gain.
- Characteristic genetic factors. Overexpression of the DSCR 1-4 gene on chromosome 21, responsible for pyruvate intolerance associated with insulin resistance, was reported [27]. By its overexpression in DS, this gene involved in energy homeostasis, was altering metabolic adjustments, raising neoglucogenesis and contributing to the development of fat mass and a metabolic syndrome.
- Particular lifestyle habits combining high degree of sedentariness [28-31] and eating disorders [18, 32-34].

In our follow-up, XY showed a height curve in the low values, characteristic of DS, but the weight curve did not show an above-average value, as did the body mass index (Figure 1). These observations were explained by a well-regulated food control by the family environment, but also by regular sports practice. XY did not present any eating disorders, even though these are frequently found in DS. Biological monitoring also confirmed that the lipidic assessments were strictly normal, as were the endocrine assessments which could reveal endocrine pathologies responsible for variations in the weight curve.

In DS, many studies proposed the implementation of regular PA sessions [28, 31, 35, 36] to control body weight for people with DS. However, these studies did not show a significant impact of PA on weight

loss but rather on body composition (decrease in body fat percentage) and on quality of life indicators [35, 36].

Moreover, other anatomical characteristics of the DS should complete the assessment of non-contraindication to the practice of sport. For example, there may be cervical instability of C1-C2, which, if confirmed, could lead to a real interdiction to the practice of certain sports (*i.e.* combat sports). The prevalence of a narrow lumbar canal that can induce significant pain when walking or practicing physical activity will also be looked up. A rigorous examination of the characteristic feet will be carried out because by being small, wide and flat, with a collapsed arch, these characteristic feet can alter balance. Some of these features (flat feet, hyperlordosis, hyperlaxity) were found in XY, and had been treated when pain was reported.

4.2 Autonomic profile and DS: bradycardia, chronotropic incompetence and blunted vagal tone

Alterations in autonomic nervous system (ANS) function are common in the DS population, at rest, during sleep, or during exercise [37-39]. In response to stress (exercise; autonomic stimulation) heart rate (HR) adaptation is lowered (10-15 beats less) [37-43]. A blunted sympathetic activation, a reduced vagal withdrawal or alterations in both branches of the ANS and baroreflex cardiac modulation may explain this poor cardiac adaptation [39, 40, 43]. These ANS alterations are found during exercise, with high parasympathetic tone [44, 45] and longer post-exercise recovery. Chronotropic incompetence may also be observed during maximal effort [43, 46, 47]. We observed these same alterations in cardiac responses to effort in XY, with chronotropic incompetence and vagal syncope's following strenuous physical effort (training) or with a competitive stress component. Baynard et al. [44] reported similar results in subjects with DS during functional explorations through treadmill exercises, confirming that dysautonomia are a common feature of the DS population. This chronotropic incompetence observed during exercise could be induced by lower catecholamine secretion or sensitivity [46]. Alterations of catecholamine secretions have thus been reported in several studies [41, 43, 48], during exercise or ANS stimulation tests. Low HR associated with lower catecholamine concentrations in young DS are common [43, 49, 50].

Finally, in spite of sports training whose volume increases regularly from adolescence to adulthood (Figure 2), the aerobic capacity of XY remained particularly stable, whereas it was expected to increase in adulthood compared to the values obtained during adolescence. It is possible that the chronotropic incompetence of XY, which increased over the years, was one of the elements that may explain this observation. Indeed, during a maximal effort test, the limiting factors of VO_{2max} may be cardiorespiratory or metabolic. The Fick-Jacobs equation [49] states that VO_{2max} depends on the HR_{max}, the systolic ejection volume and the arteriovenous difference in O_2. Therefore, the chronotropic incompetence of XY or inability to raise the HR_{max} at the end of MTT appeared to be a strong argument for not increasing the VO_2 value of XY.

Dysautonomia, chronotropic incompetence and altered neurosecretions can therefore induce a

decrease in exercise tolerance, be the cause of fatigability [43, 46, 50] and explain the appearance of post-exercise vagal syncope in DS subjects. However, the management of this dysautonomia remains complex. Some pharmacological treatments have been suggested [51] but their compliance and deleterious effects remain difficult to manage, especially in DS. Another proposal to treat this dysautonomia is based on physical training [52]. This could improve the described autonomic alterations, but in DS, the number of available works is still insufficient. However, 6 months of endurance training showed an improvement in sympatho-vagal balance in DS adults [53] and better heart rate recovery kinetics [50].

Promoting physical activity guarantees the development of the person with Down syndrome. When sports trainings are organized and accompanied by regular medical monitoring, listening to the athlete and his family, it fosters the achievement of an exceptional sports career, but also demonstrates the ability of young people with Down syndrome to develop exceptional physical qualities. It is possible to do high level sport while having DS. This can be eased if the arrangements between working and training time are organized through individual projects that promote the social integration of people with DS. The presentation of this follow-up is therefore part of this framework, the one promoting the practice of sports for people with DS, because regular physical activity benefits the health of all citizens with or without disabilities. Finally, the perspectives offered by this monitoring are a more generalized monitoring that could make it possible to determine references values for athletes with a disability.

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Conflict of Interest

The authors have indicated they have no potential conflicts of interest to disclose.

Financial Disclosure

The authors declare that they have no financial disclosure. There are no prior publications or submissions with any overlapping information, including studies and patients.

Author Contributions

V-A Bricout conceptualized and designed the study, performed the data collection, carried out the initial analyses, and drafted the initial manuscript. M Guinot, A Favre-Juvin, F Amblard, F Devillard performed the data collection, they were the medical practitioners in charge of the medical follow-up. They critically reviewed the manuscript.

All authors approved the final manuscript as submitted.

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