




Article

Evaluation of Fitness and the Balance Levels of Children with a Diagnosis of Juvenile Idiopathic Arthritis: A Pilot Study

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Abstract: Background: Juvenile idiopathic arthritis is a main cause of physical disability and has high economic costs for society. The purpose of this study was to assess the fitness levels and the postural and balance deficits with a specific test battery. **Methods:** Fifty-six subjects were enrolled in this study. Thirty-nine healthy subjects were included in the control group and seventeen in the juvenile idiopathic arthritis group. All subjects were evaluated using a posturography system. The fitness level was evaluated with a battery of tests (Abalakov test, sit-up test, hand grip test, backsaver sit and reach, the toe touch test). An unpaired *t*-test was used to determine differences. Pearson’s correlation coefficient was used to evaluate the correlation between the tests. **Results:** The battery of tests demonstrated that subjects in the juvenile idiopathic arthritis group have lower fitness levels compared to the control group. The juvenile idiopathic arthritis group showed low postural control with respect to the control group. Pearson analysis of the juvenile idiopathic arthritis group data showed significant correlations between variables. Pearson’s results from the control group data showed a similar trend. **Conclusions:** The results suggest that the battery of tests used could be an appropriate tool. However, we highlight that these conclusions need to be supported by other studies with a larger population scale.

Keywords: rheumatic diseases; test battery; juvenile idiopathic arthritis; fitness; balance; quality of life

1. Introduction

Juvenile idiopathic arthritis (JIA) is the main rheumatic disease in the pediatric age range. In the United States, a recent study has estimated that 294,000 children suffer from this disease [1]. The literature decrypted chronic arthritis in children in 1897; George Frederic Still showed the destruction of cartilage and the joint deformity related to tissue contractures caused by a lack of joint mobility [2]. On the other hand, economic questions are now central to the practice of medicine; Angelis et al. reported a significant cost burden on society [3]. JIA is a chronic childhood autoimmune disease that has significant implications for the quality of life [4]. The literature suggests that rheumatic diseases are causes of physical disability and create high societal and economic costs and absences from work [5]. This disease is epidemiologically associated with the development of cardiovascular

disease, and some researchers have found in these subjects endothelial thickening, a preclinical sign of atherosclerosis [6,7]. Fitness level is an important contributor to prevent these deficits [8]. Pain and fatigue are common in subjects with JIA and can influence school performance, family life, and an inactive lifestyle [9]. Furthermore, physical inactivity may be associated with social isolation and lead to additional burdens on the health of patients with JIA [9]. In this line Aasland et al. reported that psychosocial functioning is correlated with low levels of fitness [10]. Furthermore, Margetić et al. showed that pain perception is associated with physical disability [11]. Widespread symptoms of JIA include joint stiffness, joint swelling, decreased physical function, pain, and fatigue [12,13]. The inflammation of the synovia can create instability of the supporting structures and negatively affect the biomechanical function of the joint [14]. The disease causes a progressive deterioration and deformities of the joint, producing an articular instability [15]. In 2002, Li-Tsang et al. showed that structural changes may lead to a progressive lack of extension [16]. Commonly, exercises are used to deal with this problem [16]. The literature suggests and encourages the physical activity (PA) program because the PA provides significant general health benefits and may improve disease outcomes [17]. Takken et al. showed that the children with more severe disease were less active [18]. However, at this moment there are no PA programs incorporated into a comprehensive care plan [19]. Interestingly, in the proposal by Lelieveld et al. [20] the authors showed that an Internet-based program aimed at promoting PA in everyday life effectively improves PA in those JIA patients with low PA levels [20]. The balance control is a difficult function, the nervous system must activate many systems and process a lot of information from receptors. Subsequently, it corresponds to a specific response in order to maintain the optimal balance by neuromuscular system [21,22]. A deficit of the proprioceptive system has been shown in adult subjects with inflammatory arthritis [23]. The literature showed poor balance in arthropathy associated with hemophilia [24]. In 2013, Houghton, et al. showed that a significant proportion of children with arthritis have impaired balance [25]. On the other hand, studies showed that children with serious illnesses have a low fitness level [26]. In 2013, we ourselves have shown that serious diseases can impoverish the motor capacity and physical performance [27]. Many authors analyzed the level of fitness with a battery of tests [28–31]. The aim of this study was to assess the postural control in children with JIA and search for possible balance deficits. Furthermore, we have evaluated the physical fitness levels with a battery of tests which may be administered in small environments such as, in most cases, hospitals.

2. Materials and Methods

2.1. Study Design and Context

Our study contained both genders (Table 1). Fifty-six subjects were enrolled in this study (age: 12.68 ± 3.5 years; weight: 44.46 ± 16.53 kg; height: 149.77 ± 18.10 cm). Seventeen subjects, aged eight to 18 years (age: 12.23 ± 4.46 years; weight: 42.82 ± 11.75 kg; height: 145.88 ± 15.83 cm), have been included in the juvenile idiopathic arthritis group (JIAG). These subjects had a definite diagnosis of JIA and were followed at the Pediatric Rheumatology Program at a single hospital. The JIAG was recruited from the Pediatric Unit, ARNAS Civico, Di Cristina and Benfratelli Hospitals, Palermo, Italy. Consequently, thirty-nine subjects were included in the control group (CG). The control group was composed of children aged eight to 18 years (age: 12.87 ± 3.04 years; weight: 45.18 ± 18.32 kg; height: 151.46 ± 18.94 cm) who were healthy. According to Houghton et al., all subjects were excluded from participation if they had auditory or visual impairment (reduced visual acuity allowable if corrected with lens/glasses) or orthopedic injury involving the lower extremities [25]. The evaluations of the JIAG were collected from the same research unit during the period between December 2016 and March 2017 at the Pediatric Unit, ARNAS Civico. The evaluations of the CG were collected in the same period and by the same research unit at the Sports Science Faculty, University of Palermo. The sequence tests: at first, we evaluated the postural control and, after, we administered the physical test. This sequence has been made to not influence the postural analysis by the fatigue that there

could be after the administration of physical tests. We used some inclusion criteria to select the CG: (1) similar age, weight, height of the EG; (2) a similar geographic provenance; and (3) not having participated in any regular exercise program. Children have been selected in the study according to the criteria approved by the ethics committee of the University of Palermo. The study was performed in compliance with the Declaration of Helsinki and the principles of the Italian data protection act (196/2003) were observed. Prior to enrollment, all parents provided informed consent.

Table 1. Description of the anthropometric characteristics of the participants.

Variables	CG n = 39 (Mean ± SD)	JiAG n = 17 (Mean ± SD)	p
Age (years)	12.87 ± 3.04	12.23 ± 4.46	ns
Weight (kg)	45.18 ± 18.32	42.82 ± 11.75	ns
Height (cm)	151.46 ± 18.94	145.88 ± 15.83	ns

CG: Control Group; JiAG: Juvenile Idiopathic Arthritis Group; ns: Not Significant.

2.2. Method of Testing

2.2.1. The Posturography Analysis

The posturography test was administered with the FreeMed posturography system (the FreeMed baropodometric platform and FreeStep v.1.0.3 software, produced by Sensor Medica, Guidonia Montecelio, Roma, Italy). The platform's sensors are 24 K gold; this allows high repeatability and reliability. Furthermore, all subjects performed the posturography analysis with the Romberg test position [32]. The parameters used for balance investigation were: length of sway path of the CoP (SP); ellipse surface area (ES); and the coordinates of the CoP coordinates along the frontal (x-mean) and sagittal (y-mean) planes [33]. The ES, and the coordinates along the frontal and sagittal parameters are not modified by the sampling rate and were kept for this study, according to the 1981 Kyoto conventions [34,35].

2.2.2. Fitness Test Battery

A specific fitness test battery was used to evaluate the physical fitness level both the EG and CG. The testing battery included:

- Abalakov test [36]: when ready, the subject squats down until the knees are bent at a 90° angle while swinging the arms back behind the body; the arms move forward and the participants jumps as high as possible. The Abalakov jump is specific for maximal strength, and it is expressed on a vertical plane [31];
- The sit-up test and hand grip test [37,38]: in the first test, the subjects were instructed to bend the knees at an angle of 100°, with both arms on his hips while the ankles were held down. The subject performed the concentric movement of lifting the trunk, followed by the eccentric movement of lowering the trunk. The maximum number of executions was taken into account. The second test was an isometric grip strength for both hands, and was determined using an electronic dynamometer (KERN-MAP). The subject was standing with the shoulder adducted and neutrally rotated. The forearm was along the hips and in a neutral position. The children were told to make their best squeezing effort onto the dynamometer, one repetition with each hand, three times. The best performance for each hand was taken into account;
- Backsaver sit and reach [39–42]: the subjects sit on the floor with both legs out straight. The feet were placed flush against the measurement box. The arms were placed parallel to the floor, with the hands facing down, and the subject reached forward along the measuring line as far as possible; and

- The toe touch test [42,43]: the test was performed with the participants standing erect with feet hip-width apart on the measurement box. The subjects were instructed to bend forward as far as possible, while keeping the legs erect, with the arms fully extended.

Each test was repeated three times and the best was taken for analysis. All the tests in the battery are present in the literature for assessing the level of fitness in children [28,31,36,39,40,43].

2.3. Statistical Analysis

In order to evaluate the statistical differences in performance, the unpaired *t*-test was used. This function gives an unpaired two-sample Student's *t*-test with a confidence interval for the difference between the means. A *p* value lower than 0.05 was considered as statistically significant. The Pearson's correlation coefficient was used to evaluate the correlation between the tests. To perform the analysis, StatSoft's STATISTICA software (Windows, Vers. 8.0; Tulsa, OK, USA) was used.

3. Results

Posturography performance results of the Juvenile Idiopathic Arthritis Group (JIAG) were significantly lower compared to the control group (CG) in the length of the sway path of the Center of Pressure (CoP) (CG 543.2 ± 300.2 mm vs. JIAG 921.2 ± 430.7 mm; $p < 0.001$; Figure 1) and ellipse surface area (CG 84.47 ± 47.94 mm² vs. JIAG 165.8 ± 215.7 mm²; $p < 0.05$; Figure 2). X and Y mean show no statistically significant differences. Similarly, the fitness test results of the JIAG were significantly lower compared to the CG in the Abalakov test (38.67 ± 17.48 cm vs. 29.06 ± 12.74 cm; $p < 0.05$); hand grip test right hand (DX) (CG 23.08 ± 11.37 kg vs. JIAG 16.65 ± 7.82 kg; $p < 0.05$), and hand grip test left hand (SX) (CG 22.15 ± 10.08 kg vs. 15.64 ± 6.318 kg; $p < 0.05$) (Figures 3–5). Sit-up test, backsaver sit and reach, and the toe touch test did not show statistically significant differences. Pearson analysis of the JIAG data showed significant correlations between variables (Table 2). Pearson's results from the CG data showed a similar trend (Table 3).

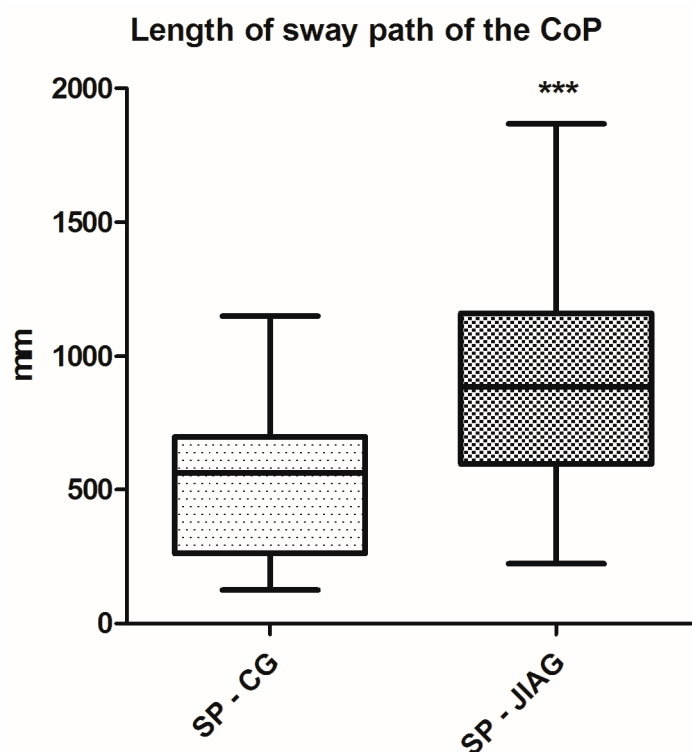


Figure 1. Analysis of length of sway path (SP) of the centre of pressure (CoP) among the group of healthy subjects (CG) and subjects with juvenile idiopathic arthritis (JIAG). *** indicated that $p < 0.0001$

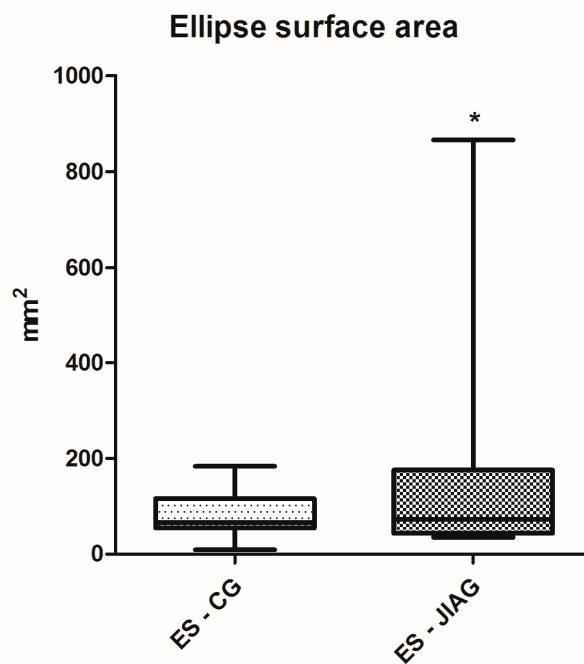


Figure 2. Analysis of ellipse surface area (ES) of the centre of pressure (CoP) among the group of healthy subjects (CG) and subjects with juvenile idiopathic arthritis (JIAG). * indicated that $p < 0.05$.

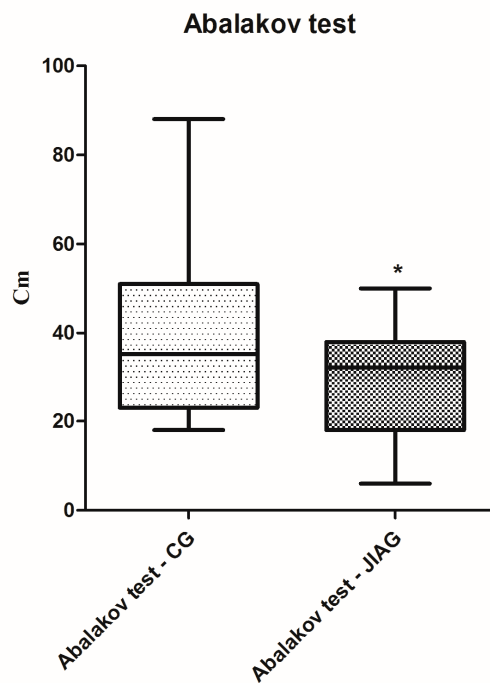


Figure 3. Analysis of Abalakov performances among the group of healthy subjects (CG) and subjects with juvenile idiopathic arthritis (JIAG). * indicated that $p < 0.05$.

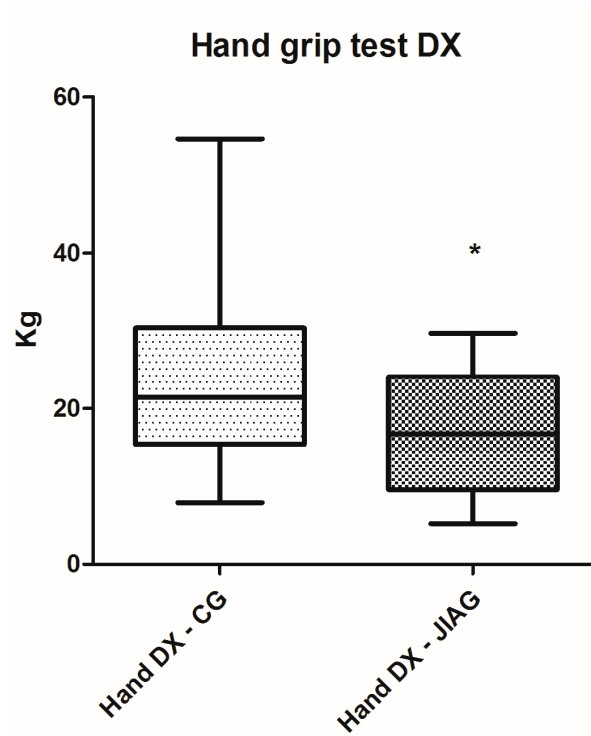


Figure 4. Analysis of hand grip (DX) performances among the group of the healthy subjects (CG) and subjects with juvenile idiopathic arthritis (JIAG). * indicated that $p < 0.05$.

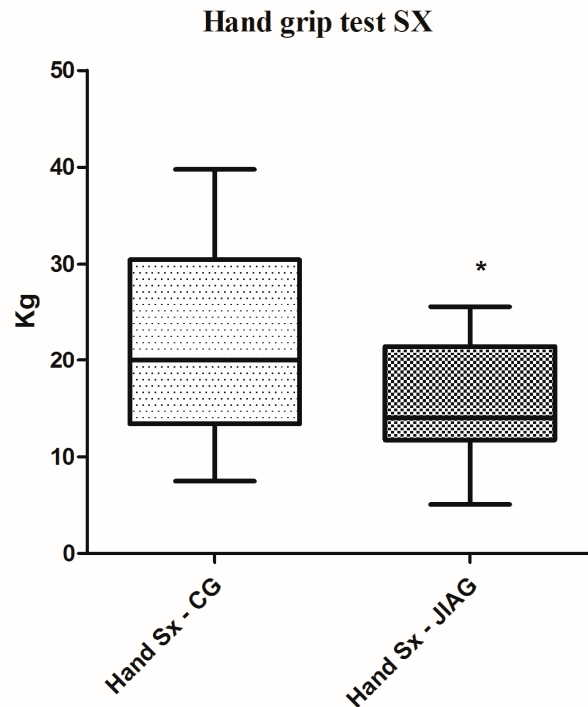


Figure 5. Analysis of hand grip (SX) performances among the group of the healthy subjects (CG) and subjects with juvenile idiopathic arthritis (JIAG). * indicated that $p < 0.05$.

Table 2. Description of the correlations between variables of JIAG groups.

Variables	Correlations JIAG Group; n = 17					
	Y Mean	Abalakov Test	Backsaver Sit and Reach	Toe Touch Test	Hand Grip DX	Hand Grip SX
ES, mm ²	−0.7	−0.74	−0.54	−0.54	−0.67	−0.59
SP, mm						
X mean					0.49	
Y mean						
Abalakov test			0.6	0.6	0.76	0.76
Backsaver Sit and Reach				0.94		
The Toe Touch Test						
Hand grip DX						0.96

DX: right hand; SX: left hand; ES: ellipse surface area; SP: length of sway path.

Table 3. Description of the correlations between variables of CG groups.

Variables	Correlations CG; n = 39				
	Abalakov Test	Backsaver Sit and Reach	Toe Touch Test	Hand Grip DX	Hand Grip SX
ES, mm ²	−0.75			−0.64	−0.73
SP, mm					
X mean		−0.64	−0.57		
Y mean					
Abalakov test				0.64	0.72
Sit up test		−0.40			
Backsaver Sit and Reach			0.88		
The Toe Touch Test					
Hand grip DX					0.91

DX: right hand; SX: left hand; ES: ellipse surface area; SP: length of sway path.

4. Discussion

This study is confirmed by previously published studies [9,44,45]. The results showed poor muscle strength and balance instability in children with juvenile idiopathic arthritis (JIA). The literature shows that center of pressure (CoP) is the primary stabilized reference for posture and movement coordination [46]. Our results confirmed the conclusion of Houghton and Guzman [25]: the children with JIA have lower postural control levels when compared to their healthy peers. To our knowledge, this study is the second, after the study of Houghton et al., to report on an assessment of balance in children with JIA and healthy controls. We believe that this is appropriate in the absence of reference values for balance measurement in children. Our data showed that ellipse surface area was statistically lower in JIAG with respect to healthy subjects. Similarly, the length of the sway path of the CoP was statistically greater than in healthy subjects. The children in this study had well-controlled disease, and we hypothesize that children with uncontrolled disease may have greater deficits in postural control. In addition, we evaluated the fitness level of the JIA group (JIAG) components and compared them with the group of healthy subjects (CG), through a specific fitness battery and, also, we have analyzed the correlation between postural analysis and the test battery.

The children with JIA have proprioceptive deficits and have a slower motor-proprioceptive response [47]. Deficits of the proprioceptive system was demonstrated in adults with increased postural sway and decreased balance caused by inflammatory arthritis [23,48]. These subjects may have a loss of mobility, exercise tolerance, muscle strength and range of motion [47]. The motor abilities (strength, power, coordination) that are necessary components of balance capacities [49] have been confirmed by our analysis. In JIAG, we showed a strong correlation between postural analysis, Abalakov test, and hand grip test (Tables 2 and 3). Consequently, new tools and new strategies for the evaluation of physical fitness in children with this diseases are needed [29,37]. As previously mentioned, the battery of tests had to meet the needs of the space of places that are typical of hospitals. Fitness tests are usually applied in sporting and fitness contexts. This study utilized a specific test battery

that included validated field-based fitness tests to gain a better understanding of physically-related consequences of this disease. The results showed a deficit in muscle strength. This result confirms the results reported in the literature [50,51]. The hand grip test was lower than in healthy subjects. A pilot study showed that children with JIA have difficulty with writing, with these limitations mainly caused by pain [52]. Earlier studies with children and adolescents report lower grip strength results in negative consequences compared with healthy subjects [53]. The Abalakov test showed a deficit in muscle strength in lower limbs; the deficits conformed to balance analysis [54].

This study has several strengths and limitations. To our knowledge, this is the first study that has used these types of tests to evaluate subjects with JIA and correlated them with postural analysis. The battery of tests are simple, fast to administer, inexpensive, reliable, and highly versatile. The limitations were that the sample with JIA was not homogeneous in terms of disease time, and patients with high disease activity may show lower performance. On the contrary, the subjects with mild disease activity may have shown higher performance levels. Furthermore, the study does not go into detail of the subjects' therapeutic plan.

5. Conclusions

In conclusion, the children with juvenile idiopathic arthritis showed a lower level of physical fitness compared to their healthy peers. This trend is also confirmed in the postural control. The subjects who participated in the study had a well-controlled and measured therapeutic plan. As a result, we hypothesize that subjects that did not properly care for the disease have greater deficits both on physical fitness and balance. Fitness tests are usually used in a sporting context but, in our experience, the battery of tests showed a good evaluation capacity, is inexpensive, reliable, and is simple and fast to administer. Our conclusions necessitate further support by a larger population scale. Future studies should identify a specific training protocol for muscle strength to balance deficits and, ultimately, improve the quality of present and future life.

Author Contributions: Antonino Patti and Antonio Palma designed the study, discussed the results and drafted the paper, Giuseppe Messina performed the testing and participated in drafting paper; Giovanni Corsello and Angelo Iovane helped with discussion of results and overviewed previous researches; Maria Cristina Maggio did statistical analyses and drafted the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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