Excellent balance skills despite active and inactive juvenile idiopathic arthritis - unexpected results of a cross-sectional study

J. Merker[1,2], M. Hartmann[2], F. Kreuzpointner[1], A. Schwirtz[1], J.-P. Haas[2]

[1]Department of Biomechanics in Sports, Faculty of Sports and Health Sciences, Technical University of Munich, Germany; [2]German Center for Pediatric and Adolescent Rheumatology, Garmisch-Partenkirchen, Germany.

Abstract

Objective

Postural control (PC) is fundamental for human movements. Different factors, such as injuries or diseases, can adversely affect PC. The purpose of this study was to evaluate PC in juvenile idiopathic arthritis (JIA) patients with different disease activity levels in comparison to healthy peers.

Methods

JIA patients with active and inactive lower limb joints (n=36 each group) were examined. Both groups have been on medication and have had physiotherapy for at least 5 years. For comparison, an age- and gender-matched healthy control group (CG; n=36) participated. PC was measured bipedal on a balance-board (S3-Check, TST, Großhoeflein), with an instable tilting between left and right. The parameters of interest were the best results of Stability Index (STI), Sensorimotor Index (SMI) and Symmetry Index (SYI) out of 4 test trials as well as JIA disease-related variables. Data were analysed with descriptive statistics, comparison of averages, linear regression and correlations ($p<0.05$).

Results

The three groups showed no differences in anthropometric characteristics and SYI ($p>0.05$). In both JIA groups, STI and SMI were lower than indices of CG ($p<0.05$), indicating better stability and motor control. Balance indices did not differ between active and inactive JIA patients ($p>0.05$).

Conclusion

JIA patients showed better PC than CG. Possible explanations are an increased body-awareness due to long-term physiotherapy and daily coordination training due to compensatory movements. The positive results highlight the success of individual, interdisciplinary treatment in JIA and can be used to promote recommendations for safe sport participation.

Key words

postural balance, juvenile idiopathic arthritis, child

Josephine Merker, MA
Matthias Hartmann, MSc
Florian Kreuzpointner, PhD
Ansgar Schwirtz, PhD, Prof.
Johannes-Peter Haas, MD, Prof.

Please address correspondence to:
Josephine Merker,
Georg-Brauchle-Ring 60/62,
80992 Munich, Germany.
E-mail: josephine.merker@tum.de

Received on June 30, 2016; accepted in revised form on November 4, 2016.

Competing interests: none declared.

Introduction

Postural control (PC) is fundamental in everyday life and for physical activities (1). It is a complex motor skill, meaning the ability to maintain the body's center of mass balanced over the base of support in static and dynamic situations (2, 3). The control of postural stability requires constant interactions of peripheral (visual, vestibular and somatosensory systems) and central components of the nervous system to derive appropriate neuromuscular responses (2). Different factors, such as age, gender, weight, pain, injuries or diseases, may adversely affect functional balance tasks (4-10).

Motor skills and functional ability may be limited in children and young adults with juvenile idiopathic arthritis (JIA) due to joint swelling, pain, decreased proprioception of the affected joints, loss of joint range of motion, muscle weakness, and contractures (11). JIA is the most common chronic rheumatic disease of childhood primarily involving joints (12). The levels of disease activity may vary in terms of symptoms within the course of disease: The active arthritis causes a significant nociceptive reaction, which is often followed by muscular imbalance and malpositioning of the affected joints (13). A successful therapy leads to an inactive disease level. Especially physiotherapy becomes an important part of disease-management in order to prevent fixed deformities (13). After six months of inactive synovitis, the disease level changes by definition to clinical remission on medication or to clinical remission off medication (14).

Despite substantial improvements in pharmacological management of JIA in the last decade, patients still have functional disabilities independent of the disease activity levels (15). For example, several studies reported gait deviations (16-19) or affected foot motion in individuals with JIA (20-22). A few studies examined poor balance in JIA patients with different types of tests and methods (23-27). However, reports of PC in children with JIA and different disease activity levels are limited and only small sample sizes are investigated (24).

It has been demonstrated that children with active JIA have poorer physical function, reduced daily activities and a lower health-related quality of life (28-30). Therefore, we examined active and inactive patients separately to counteract a bias evoked by reduced physical activity due to disease activity. The quantification of PC in JIA patients with different disease status is necessary to assess motor skills and a level of functional ability in order to start an appropriate therapy plan and to give recommendations for activities in daily life.

The aim of this study was to investigate PC on an unstable surface in JIA patients with active and inactive synovitis of lower extremity joints and healthy peers. The first study hypothesis was that children with JIA have significant impairments in PC compared to healthy controls. Secondly, we expected poorer PC in JIA patients with active than in those with inactive synovitis.

Participants and methods

Participants

Seventy-two JIA patients from the German Center for Pediatric and Adolescent Rheumatology between 8 and 18 years were included in this study. The JIA diagnosis was classified according to the 2004 ILAR classification criteria (31) and patients were divided into two groups (Table I and II). The major inclusion criterion of the first group was active arthritis (*i.e.* swollen and/or painful joints) of at least one lower limb joint at the time of testing (active JIA group). The second group included those JIA patients with inactive joints (no active synovitis) of the lower limbs at the time of investigation (inactive JIA group). An inactive joint was defined with no swelling, no pain, no synovitis and/or limited range of motion (LROM). The disease activity level was determined by the attending physician of each patient according to Wallace *et al.* (14). All clinically relevant joints were assessed by using ultrasound. Clinical relevant joints were defined as joints with swelling, overheating, pain and/or LROM according to the first clinical examination of the current clinic visit or during the last clinic visit. JIA patients with active uveitis, intra-articular corticosteroid injections less than four weeks prior to the assessment, major

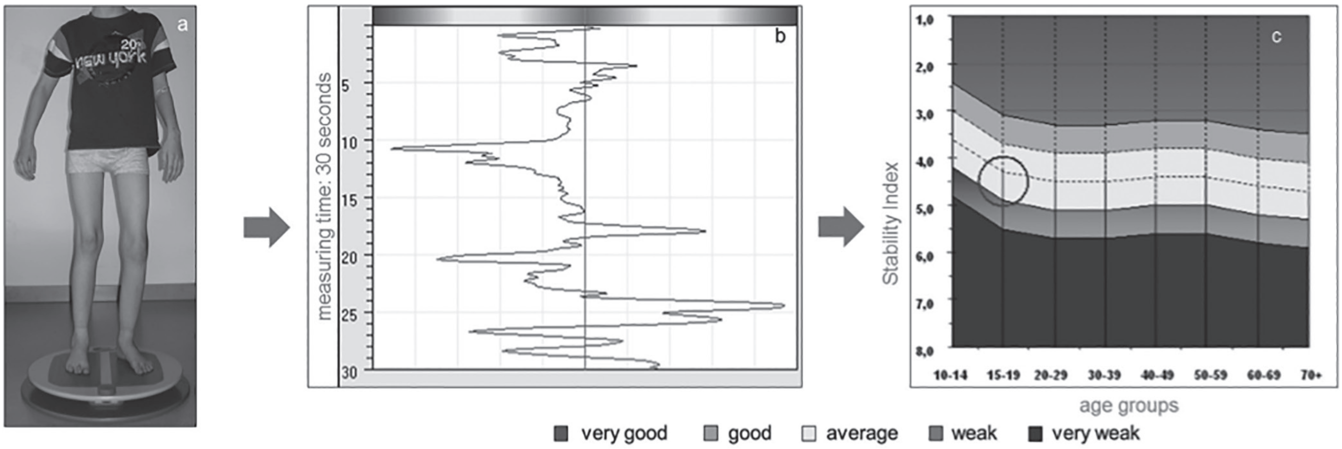

Fig. 1. a: A JIA patient on the S3 Check. **b**: The resultant curve of progression from left to right of the balance board. The vertical line means the optimal, horizontal balance board. **c**: An example of the STI outcome parameter in relation to standardised scores of the age groups.

lower extremity surgeries, neurological diseases or chronic pain were excluded from participation.

Disease-related variables were: age of onset of disease, duration of JIA disease, active joint count in total and of the lower extremities, number of joints with LROM (joint restriction >10° compared to reference (32, 33)), physician and patient global assessment of overall disease activity (variable of ACR Pediatric core set (34)), pain intensity (rated on a 100-mm visual analogue scale (VAS) (35, 36)), current medications, and history of physiotherapy. The overall disease activity was determined with the Juvenile Arthritis Disease Activity Score for 71 joints (JADAS-71) (37). The functional ability assessment was carried out with the German version of the Childhood Health Assessment Questionnaire (CHAQ) (38). None of the patients were tested in the morning, in order to eliminate effects of morning stiffness.

For comparison, an age- and gender-matched healthy control group (CG) with no rheumatic, orthopaedic or neurological diseases was included (Table I). The controls originate from a pool of 90 healthy children, recruited from surrounding schools, acquaintances and hospital staff for a comprehensive study of physical function in healthy children (unpublished study). The data matching of all three study groups was done manually according to best fit for gender, secondly for age and if possible for weight and height.

The study followed the principles of the Declaration of Helsinki and was approved by the Human Ethics Committee of the Technical University of Munich (Reference 351/14). Informed consent was obtained from all participants and their parents.

Data collection and processing

PC was measured with the S3-Check (TST, Großhoeflein, Austria) (Fig. Ia). This is a validated measurement system for functional evaluation of human stability and sensorimotor ability of the body (39, 40). It detects the current state of the sensorimotor regulatory capacity in both healthy and patients with chronic musculoskeletal complaints from the age of 7 years (40). The S3-Check is a 53 cm wide and round board with an integrated absolute position transducer. It has one axis of rotation, which enables an alternation up to an overturning of 12° from left to right. Displacements of the subject's centre of mass from the axis of rotation provoke a lateral overturning of the balance board. The transducer detects these movements (measurement accuracy: <0.5°; sampling rate: 100Hz) and the accompanying software records them (Fig. Ib) (39).

Three diagnostic experienced examiners carried out the measurements on the S3-Check, which were performed under standardised conditions in a calm environment: The child was standing barefooted on the S3-Check with feet shoulder-width apart, an arbitrary arm position and eyes open. This standing position was individually controlled for all measurements by fixed lines on the balance board surface. The subjects were told to keep the board as horizontal as possible for 30 seconds. All children completed a short test trial in order to get accustomed to the test situation and to find a convenient individual standing position on the balance board. Before the measurement started, all participants had ten seconds to reach their balanced position on the testing device. During the last three seconds a beep informed the subjects about the flying start. The balance measurement was repeated four times with a given testing time of 30 seconds and a 30-second break afterwards. Longitudinal data of 73 JIA patients had already shown (unpublished) that this standard procedure would not lead to training effects in balance ability.

Three outcome indices were obtained from the recorded data of the position transducer: S3 Sensorimotor Index (SMI), S3 Symmetry Index (SYI) and S3 Stability Index (STI). The SMI provides information about the sensorimotor ability to regulate during a balancing exercise. Therefore, the position transducer documented the quantity and quality of the motion adjustments and their course during the measurement (39). The SYI describes deviations of the balance board to the left and right and provides an indication of the ability to keep the board horizontal during testing time (39). The Stability Index (STI) is derived from SMI and SYI and indicates the complex sensorimotor performance of the tested subjects. It provides information about the ability of the participants to control their posture and

Table I. Demographics and results of balance testing of JIA patients with active JIA joints (JIA-P active) in comparison to JIA patients with inactive joints of the lower limb (JIA-P inactive) and control group (CG).

	JIA-P active (n=36) Mean (SD)	JIA-P inactive (n=36) Mean (SD)	CG (n=36) Mean (SD)	JIA-P active to JIA-P inactive *p*-value	JIA-P active to CG *p*-value	JIA-P inactive to CG *p*-value
Age [yr] [a]	13.7 (3.4)	13.5 (3.1)	13.3 (3.2)	> 0.999	> 0.999	> 0.999
Height [m] [a]	1.58 (0.18)	1.55 (0.15)	1.56 (0.17)	> 0.999	> 0.999	> 0.999
Weight [kg] [a]	51.7 (19.7)	50.0 (19.6)	48.3 (16.0)	> 0.999	> 0.999	> 0.999
S3 Stability Index best [a]	3.2 (1.3)	3.0 (1.3)	4.1 (1.1)	> 0.999	0.009*	0.001*
S3 Stability Index best, adjusted [b]	3.1	3.0	4.1	> 0.999	< 0.001*	< 0.001*
S3 Sensorimotor Index best [a]	2.6 (1.1)	2.2 (1.1)	3.3 (1.1)	0.501	0.017*	< 0.001*
S3 Sensorimotor Index best, adjusted [b]	2.5	2.2	3.4	0.365	< 0.001*	< 0.001*
S3 Symmetry Index best ratio [%] [a]	47:53 (0.1)	47:53 (0.1)	48:52 (0.4)	0.785	> 0.999	0.386

*$p<0.05$. [a]one-way ANOVA with Bonferroni correction; [b]MANOCA with Bonferroni correction.

to steady their body in a balance task (39). Both, the SMI and STI are rated on a one-to-nine-point scale with the minimal score of 1 (*i.e.* very good) to the maximal score of 9 (*i.e.* very weak) (Fig. Ic) (39). The SYI quantified three categories: no preference of one side *i.e.*, 40:60 % to 50:50 %), poor preference of one side (*i.e.* 25:75 % to 39:61 %) and severe preference of one side (*i.e.* <24:76 %) (39). The aim for an optimal symmetry proportion should be 50:50%.

For the statistical analysis, the best of each resultant index out of the four balance trials was selected in order to eliminate effects of habituation and fatigue during testing.

Statistical analysis

SPSS 23.0 was used for the statistical analysis (IBM, Armonk, USA). All data were considered normal through quantile-quantile plot analysis. A simple linear regression analysis was performed to determine the extent of relationship between demographic data and balance indices. One-way analysis of variance (ANOVA) was used to analyse differences in SYI and demographic data between JIA patients and CG. Hypotheses were assessed using multivariate analysis of covariance (MANCOVA) to identify significant differences between the active JIA group, the inactive JIA group and CG for STI and SMI. The independent samples *t*-test was used for comparison of the JIA disease-related variables between the active and inactive JIA group. In addition, a Pearson's correlation was done to investigate relationships between STI, SMI, SYI and JIA disease outcome parameters. An alpha level of 0.05 was selected, and a Bonferroni post hoc correction was applied to account for multiple comparisons in ANOVA and MANCOVA statistics.

Results

Participants

A total of 108 children were included in the study. All three groups were matched according to age, gender, body weight and height ($p>0.999$). Finally, 15 boys and 21 girls participated in each group. All demographic data are summarised in Table I.

On average, the JIA disease began at the age of 8.0 (SD 4.8) in the active and 6.5 (SD 4.8) in the inactive group (Table II). The mean disease duration was approximately 1.5 years longer in inactive patients compared to those with active JIA ($p=0.242$). Both groups consisted of patients with different JIA subtypes (Table III). All three JIA patients with psoriatic arthritis had a polyarticular disease course (41). Active joint count in total ($p<0.001$) and of the lower extremity ($p<0.001$) as well as the number of joints with LROM (total: $p=0.003$; lower extremity: $p=0.011$) were higher in the active JIA group (Table II). All joints of inactive patients had no active synovitis, except for one patient with an active arthritis in the wrist. The exact number of active and inactive joints as well as joints with LROM of the lower extremity are listed in Table III. Disease activity, assessed with the JADAS-71, the physician and patient-reported global assessment of disease activity was significantly higher in the active JIA patients ($p<0.001$). An increased pain intensity was reported compared to the inactive JIA patient group with statistically significance after measurement ($p=0.042$). All JIA patients were on anti-inflammatory and/or immuno-suppressiva medication (Table III). In the home care setting, both patient groups were treated with physiotherapy once or twice a week according to the "Garmisch Treatment Concept" (13). Nevertheless, both patient groups showed increased number of LROM joints. However, one third of the inactive group had no LROM of lower extremity joints. Most limited in passive movement of inactive patients were the knee joints. The disease duration did not correlate with the number of LROM joints ($r=0.10$, $p=0.551$). The overall period of physiotherapy was 18 months longer in inactive patients than in active JIA patients ($p=0.155$). The results of the CHAQ disability score indicated low scores and mild restrictions in functional ability in both JIA groups ($p=0.312$).

Balance indices

The results of balance indices are summarised in Table I. SYI were within the normal range (40:60% to 50:50%) and none of the investigation groups had any preferences for one side ($p>0.05$). The simple linear regression analysis revealed that body weight was found

Table II. Disease characteristics of JIA patients with active JIA joints (JIA-P active) in comparison to JIA patients with inactive joints of the lower limb (JIA-P inactive).

	JIA-P active (n=36) Mean (SD)	JIA-P inactive (n=36) Mean (SD)	*p*-value[a]
Age of onset of disease [yr]	8.0 (4.8)	6.5 (4.8)	0.18
Duration of disease [yr]	5.6 (5.2)	7.0 (4.6)	0.242
JADAS-71	17.1 (12.6)[2]	4.1 (2.9)[1]	<0.001*
PedACR physician [mm]	47 (22)	16 (12)	<0.001*
PedACR patient [mm]	43 (23)[2]	20 (15)[1]	<0.001*
CHAQ	0.325 (0.389)[2]	0.223 (0.426)[1]	0.312
Total JIA active joints	8 (10)	0 (1)	<0.001*
JIA active joints lower extremity	3 (2)	0 (0)	<0.001*
Total joints with LROM	8 (9)[3]	3 (3)[3]	0.003*
Joints with LROM lower extremity	4 (2)	2 (2)	0.011*
Pain VAS before measurement [mm]	11 (25)	5 (13)	0.257
Number of patients without any pain before measurement [%]	81	81	-
Pain VAS after measurement [mm]	16 (28)	5 (12)	0.042*
Number of patients without any pain after measurement [%]	67	81	-
Period physiotherapy [yr]	4.5 (5.1)	6.1 (4.6)	0.155
Frequency of physiotherapy per week	1.3 (0.7)	1.3 (0.5)[3]	0.947

[a]independent *t*-test *$p<0.05$. [1]results of n=33; [2]results of n=34; [3]results of n=35.
LROM: limited range of motion; VAS: visual analogue scale.

Table III. Summary of disease subtypes, affected joints of the lower extremity and anti-inflammatory and/or immuno-suppressiva medication.

		JIA-P active n	JIA-P inactive n
JIA subtypes	Enthesitis-related arthritis	6	4
	Extended oligoarthritis	12	9
	Persistent oligoarthritis	0	7
	Polyarthritis (RF-)	13	12
	Psoriatic arthritis	2	1
	Systemic arthritis	1	1
	Undifferentiated arthritis with polyarticular disease course	2	2
Sacrum	Active, left/right ǀ Inactive left/right	2/3 ǀ -	- ǀ 1/0
	LROM, left/right	1/1	-
Hip	Active, left/right ǀ Inactive left/right	5/6 ǀ 5/4	- ǀ 14/12
	LROM, left/right	19/21	12/11
Knee	Active, left/right ǀ Inactive left/right	19/19 ǀ 8/8	- ǀ 29/32
	LROM, left/right	24/24	21/20
Ankle	Active, left/right ǀ Inactive left/right	20/18 ǀ 9/8	- ǀ 21/21
	LROM, left/right	23/20	11/11
Foot	Active, left/right ǀ Inactive left/right	6/9 ǀ 1/1	- ǀ 10/10
	LROM, left/right	3/2	1/1
medication	Disease modifying antirheumatic drugs (DMARDs)	26	30
	TNF-α blocker	36	14
	Non-steroidal anti-inflammatory drugs (NSAIDs)	27	12
	Cortisone	2	2

RF: rheumatoid factor; LROM: limited range of motion.

to predict SMI and STI ($R^2=0.614$, $\beta_i=0.737$, $p<0.001$). The adjusted means of STI and SMI were significantly lower in both patient groups compared to CG, indicating a better postural stability and sensorimotor regulation ability in patients than in healthy peers ($p<0.001$). No differences were found in STI ($p>0.999$) and SMI ($p=0.365$) between the active and inactive JIA group. There were only weak correlations between balance indices and disease outcome parameters (Table IV). Assessment of pain before measurement demonstrated weak correlation with STI ($r=0.24$, $p=0.046$) and a fair correlation with SYI ($r=0.27$, $p=0.024$). Further analyses comparing JIA patients with and without any pain before and after measurement (Table II) revealed no differences in balance indices between pain and disease activity groups ($p>0.05$). CHAQ had a little correlation with SMI.

Discussion

In this study, PC was measured on an unstable surface in two JIA patient groups with different disease activity levels and in a healthy control group. The results demonstrate that JIA patients react more precisely to variable positions of the balance board than healthy peers. Both patient groups had better postural control and were able to steady their body on the S3-Check above normal ranges irrespective of disease activity. This contradicted the study's hypothesis, expecting that JIA patients have a higher dynamic postural instability with an increasing level of disease activity.

A number of previous studies showed that anthropometric factors influenced postural dynamic balance (6, 9, 42-44). For this reason, all groups investigated within this study were matched in age, gender, body weight and height ($p>0.05$). Furthermore, a regression analysis was done and body weight was used as covariate in the comparison of balance indices between groups. Therefore, differences in PC cannot be attributed to variation in anthropometric data.

Further aspects such as diseases may also contribute to changes in PC (3, 39). Studies of, for example, hemophiliac children demonstrated significant postural disharmonies as compared to age-matched healthy peers (45, 46). In JIA patients, disease-related characteristics such as pain, muscle weakness (24), reduced lower extremity strength (47), and decreased range of movement (16) can cause balance problems. However, the results of this study show better PC in JIA patients, which was unexpected. Moreover, balance indices do not seem to result from disease-related variables such as JADAS-71, active lower limb joints or joints with LROM. Only CHAQ and pain before measurement might affect STI, SYI or SMI. Nevertheless, a further grouping of active and inactive patients showed no differences in PC between patients with and those without any pain before and after measurement.

Our findings are not completely consistent with previous studies of PC in JIA patients (24-27). Reasons for this could be the age difference, disease-related factors and PC evaluation methods. Houghton et al. (24) reported on gross impairments in single-leg balance and mild impairments in bilateral dynamic balance tested with the Biodex Balance System (BBS). They found no differences in balance outcome of five patients with one or two active JIA joints compared to 20 patients with inactive joints (24). A study of 50 JIA polyarthritis patients found an impaired balance also using the BBS (25). Even after a 6-week aquatic exercise programme, no improvement in single-leg balance could be noted (27). In contrast, André (26) described improved balance ability of JIA patients after wearing a period of orthotics. Furthermore, Baydogan *et al.* (23) reported on positive effects on balance of both strengthening and proprioceptive-balance exercises. Studies focusing on balance ability of adults with RA demonstrated similar results as described in JIA patients (6, 7, 9, 47) and disease activity neither seems to be an indicator for poor balance in RA (6, 7).

Table IV. Summary of the correlations (Pearson's r) between the disease-related variables of JIA patients and balance indices.

	Total JIA-P sample (n=72)					
	S3 Stability Index best		S3 Sensorimotor Index best		S3 Symmetry Index best ratio	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value
Age of onset of disease	0.125	0.297	0.160	0.180	0.088	0.462
Duration of disease	0.231	0.051	0.165	0.166	0.050	0.676
JADAS-71[2]	-0.079	0.523	0.004	0.972	-0.105	0.399
PedACR physician[1]	-0.038	0.761	0.035	0.777	0.011	0.930
PedACR patient[2]	0.100	0.419	0.090	0.470	0.015	0.907
CHAQ[2]	-0.233	0.058	-0.252	0.040*	0.105	0.398
JIA active joints lower extremity	0.123	0.302	0.184	0.122	-0.054	0.654
Joints with LROM lower extremity	0.136	0.253	0.077	0.519	0.046	0.703
Pain VAS before measurement	0.236	0.046*	0.142	0.234	0.265	0.024*
Pain VAS after measurement	0.218	0.066	0.116	0.331	0.228	0.054
Period physiotherapy	0.227	0.055	0.189	0.113	0.041	0.733
Frequency of physiotherapy per week	0.090	0.451	-0.039	0.746	0.142	0.235

[1]results of n=68; [2]results of n=67. *$p<0.05$.
LROM: limited range of motion; VAS: visual analogue scale.

Explanations for good balance ability in JIA patients

Our study indicates that there is no relationship between JIA disease activity and PC, which confirms earlier observations for the first time in a large cohort. Moreover, our results show that pathological processes occurring in JIA do not lead to impairment in processing of central and peripheral sensory information. Children with JIA are better in the tested balance task than healthy peers. This might be explained by two mechanisms, which are not mutually exclusive: first, an increased body awareness of JIA patients acquired through long-term functional physiotherapy could contribute to better balance ability, although patients still have LROM in many lower extremity joints (15, 48). In contrast, there was no history of physical therapy in healthy participants. Physical therapies are important components of multidisciplinary JIA treatment with the aim of recovering function to improve the quality of life (49). A few physiotherapy exercises were conducted on an unstable surface (*e.g.* balance disks, balance boards, Airex® balance pad). All these exercises forced the JIA patients to keep control of posture on an unstable surface and supported an improved integration of information from the vestibular, visual, somatosensory and musculoskeletal systems. In consequence, we suspect that the JIA affected children practiced the complex control mechanism more with functional treatment than healthy children with daily activities. In addition, we assume that the German physiotherapy treatment approach (50) is an important factor for the described positive balance skills of our investigated JIA patient groups, which could further explain the differences to previous results of JIA balance studies (24, 25).

Our second explanation for the better PC is based on the pathophysiology of the development of malpositions and deformities in JIA patients due to pain and LROM in joints. The significant nociception in arthritis is transferred to different levels of the central nervous system and results in relieve positions of affected joints and in muscular imbalance (13). These reflexive pain-relieving positions and resultant deformities are frequently associated with impairments in gait function (16). In general, the control of postural and locomotors equilibrium during walking is very complex. The body centre of mass and the positioning of the base of support has to be constantly controlled during walking to maintain postural balance, and to prevent falling (51). Furthermore, the general aim of patients' locomotion is to move efficiently with a minimum of energy and if possible without pain. In consequence, permanent subconscious adaptations of relieving positions to achieve painless JIA joints may possibly practice PC during all activities of JIA patients in daily living.

Limitations and possible effects of short term disease in a complex measurement setting

This study is not without limitations. We assessed the complex motor coordination and PC with the S3-Check. Other tests or methods for quantification of PC were not used in this study. Furthermore, we investigated PC in one condition only. Evaluation of PC in standing on an unstable surface with eyes closed or while doing a secondary attention-demanding task was not included in this study due to considerations about patients' security. Finally, we did not study the physical activity or the sport participation of the JIA patients and CG. We cannot comment on possible relationships between physical activity and PC. In general, JIA patients participate in sport activities, but with limitations depending on disease course and disease activity (11).

Findings and limitations of this study also provide the basis for future research. Future studies on PC will address increased levels of difficulty, *e.g*. single-leg stance, eyes closed or a secondary attention-demanding task, to confirm our results and to discover if JIA patients with shorter disease duration still have better PC than healthy peers.

Conclusions

In conclusion, the findings of this study suggest that PC is not impaired in patients with JIA. In both JIA groups, we obtained better balance parameters than in the group of healthy peers. Furthermore, the disease activity had no significant influence on PC and there were no or only weak correlations between JIA disease-related variables and balance indices. These results are unexpected and mostly different to previous balance studies of JIA patients. Possible explanations for the good balance findings are: increased body-awareness in JIA patients due to regular and individual long-term physiotherapy, and daily coordination training due to reflexive pain-relieving positions of affected JIA joints.

The results monitor the success and the significance of individual, interdisciplinary treatment in JIA patients. They may encourage patients to become more active in daily life and to participate more in sport activities. This may improve the quality of life of children with JIA. PC is a fundamental component of all human movements, and coordination skills are prerequisites for physical fitness. Therefore, findings in balance assessments should be used to promote recommendations for safe sport participation of patients with JIA.

Acknowledgements

The authors would like to thank Iron-man-Hilfe Kinderrheuma, Pfizer Inc. Germany and the German Foundation Deutsche Kinderrheuma-Stiftung for supporting the research project leading to this paper, and all volunteers who participated in this study.

References

1. POLLOCK AS, DURWARD BR, ROWE PJ: What is balance? *Clinical Rehabilitation* 2000; 14: 402-6.
2. WESTCOTT S, PAX LOVES L, RICHARDSON P-K: Evaluation of postural stability in children: Current theories and assessment tools. *Phys Ther* 1997; 77: 629-45.
3. WINTER DA: Human balance and posture control during standing and walking. *Gait Posture* 1995; 3: 193-214.
4. MALONE A, KIERNAN D, FRENCH H, SAUNDERS V, O'BRIEN T: Do children with cerebral palsy change their gait when walking over uneven ground? *Gait Posture* 2015; 41: 716-21.
5. ESCULIER J-F, VAUDRIN J, BÉRIAULT P, GAGNON K, TREMBLAY LE: Home-based balance training programme using Wii Fit with balance board for parkinson's disease: a pilot study. *J Rehabil Med* 2012; 44: 144-50.
6. AYDOG E, BAL A, AYDOG ST, CAKCI A: Evaluation of dynamic postural balance using the Biodex Stability System in rheumatoid arthritis patients. *Clin Rheumatol* 2006; 25: 462-7.
7. HEN SSKTA, GEURTS ACH, VAN'T PAD BOSCH P, LAAN RFJM, MULDER T: Postural control in rheumatoid arthritis patients scheduled for total knee arthroplasty. *Arch Phys Med Rehabil* 2000; 81: 1489-93.
8. GOULDING A, JONES IE, TAYLOR RW, PIGGOT JM, TAYLOR D: Dynamic and static tests of balance and postural sway in boys: effects of previous wrist bone fractures and high adiposity. *Gait Posture* 2003; 17: 136-41.
9. EKDAHL C, ANDERSSON SI: Standing balance in rheumatoid arthritis. *Scand J Rheumatology* 1989; 18: 33-42.
10. BAIERLE T, KROMER T, PETERMANN C, MAGOSCH P, LUOMAJOKI H: Balance ability and postural stability among patients with painful shoulder disorders and healthy controls. *BMC Musculoskelet Disord* 2013; 14. doi: 10.1186/1471-2474-14-282.
11. TAKKEN T, VAN DER NET J, KUIS W, HELDERS PJM: Physical activity and health related physical fitness in children with juvenile idiopathic arthritis. *Ann Rheum Dis* 2003; 62: 885-9.
12. RAVELLI A, MARTINI A: Juvenile idiopathic arthritis. *Lancet* 2007; 369: 767-78.
13. HAEFNER R, TRUCKENBRODT H, SPAMER M: Rehabilitation in children with juvenile chronic arthritis. *Baillieres Clin Rheumatol* 1998; 12: 329-61.
14. WALLACE CA, RUPERTO N, GIANNINI EH: Preliminary criteria for clinical remission for select categories of juvenile idiopathic arthritis. *J Rheumatol* 2004; 31: 2290-4.
15. KLEPPER SE: Making the case for exercise in children with juvenile idiopathic arthritis: What we know and where we go from here. *Arthritis Rheum* 2007; 57: 887-90.
16. HARTMANN M, KREUZPOINTNER F, HAEFNER R, MICHELS H, SCHWIRTZ A, HAAS JP: Effects of juvenile idiopathic arhtritis on kinematics and kinetics of the lower extremities call for consequences in physical activities recommendations. *Int J Pediatr* 2010; 2010: 835984.
17. ESBJÖRNSSON A-C, IVERSEN MD, ANDRÉ M, HAGELBERG S, SCHWARTZ MH, BROSTROEM E: Effect of intraarticular corticosteroid foot injections on walking function in children with juvenile idiopathic arthritis. *Arthritis Care Res* 2015; 67: 1693-701.
18. BROSTROEM E, HAGLUND-AKERLIND Y, HAGELBERG S, CRESSWELL AG: Gait in children with juvenile chronic arthritis. Timing and force parameters. *Scand J Rheumatology* 2002; 31: 317-23.
19. BROSTROEM E, HAGELBERG S, HAGLUND-AKERLIND Y: Effect of joint injections in children with juvenile idiopathic arthritis: evaluation by 3D-gait analysis. *Acta Paediatr* 2004; 93: 906-10.
20. MERKER J, HARTMANN M, KREUZPOINTNER F, SCHWIRTZ A, HAAS J-P: Pathophysiology of juvenile idiopathic arthritis induced pes planovalgus in static and walking condition - A functional view using 3D gait analysis. *Pediatr Rheumatol Online* 2015; 13: 1-11.
21. BROSTROEM E, NORDLUND MM, CRESSWELL AG: Plantar- & dorsiflexor strength in prepubertal girls with juvenile idiopathic arthritis. *Arch Phys Med Rehabil* 2004; 85: 1224-30.
22. ANDRÉ M, HAGELBERG S, STENSTROEM C: The Juvenile Arthritis Foot Disability Index: development and evaluation of measurement properties. *J Rheumatol* 2004; 31: 2488-93.
23. BAYDOGAN SN, TARAKCI E, KASAPCOPUR O: Effect of strengthening versus balance-proprioceptive exercises on lower extremity function in patients with juvenile idiopathic arthritis. *Am J Phys Med Rehabil* 2015; 94: 417-28.
24. HOUGHTON KM, GUZMAN J: Evaluation of static and dynamic postural balance in chlidren with juvenile idiopathic arthritis. *Pediatr Phys Ther* 2013; 25: 150-7.
25. BUENO V, LEN CA, TERRERI MT, NATOUR J, HILARIO MO: Balance ability in polyarticular juvenile idiopathic arthritis. *Arthritis Rheum* 2009; 60 (Suppl. 10): 1114.
26. ANDRÉ M: Patient education and foot disability in juvenile idiopathic arthritis: A physiotherapy perspective. Stockholm, Sweden: Karolinska University Hospital; 2005.
27. BACON MC, NICHOLSON C, BINDER H, WHITE PH: Juvenile rheumatoid arthritis: Aquatic excercise and lower-extremity function. *Arthritis Care Res* 1991; 4: 102-5.
28. RINGOLD S, WALLACE CA, RIVARA FP: Health-related quality of life, physical function, fatigue, and disease activity in children with established polyarticular juvenile idiopathic arthritis. *J Rheumatol* 2009; 36: 1330-6.
29. TAKKEN T, HEMEL A, VAN DER NET J, HELDERS PJM: Aerobic fitness in children

with juvenile idiopathic arthritis: a systematic review. *J Rheumatol* 2002; 29: 2643-7.
30. OLIVEIRA S, RAVELLI A, PISTORIO A *et al*.: Proxy-reported health-related quality of life of patients with juvenile idiopathic arthritis: The Pediatric Rheumatology International Trials Organization Multinational Quality of Life Cohort Study. *Arthritis Rheum* 2007; 57: 35-43.
31. PETTY RE, SOUTWOOD TR, MANNERS P *et al*.: International league of associations for rheumatology classification of juvenile idiopathic arthritis: second revision, Edmonton, 2001. *J Rheumatol* 2004; 31: 390-2.
32. CAVE EF, ROBERTS SM: A method for measuring and recording joint function. *J Bone Joint Surg Am* 1936; 18: 455-65.
33. HEPP WR, DEBRUNNER HU: Orthopädisches Diagnostikum. 7 ed. Stuttgart: Thieme; 2004.
34. GIANNINI EH, RUPERTO N, RAVELLI A, LOVELL DJ, FELSON DT, MARTINI A: Preliminary definition of improvement in juvenile arthritis. *Arthritis Rheum* 1997; 40: 1202-9.
35. HICKS CL, VON BAEYER CL, SPAFFORD PA, VAN KORLAAR I, GOODENOUGH B: The Faces Pain Scale - Revised: toward a common metric in pediatric pain measurement. *Pain* 2001; 93: 173-83.
36. PRICE DD, MCGRATH PA, RAFII A, BUCKINGHAM B: The validation analogue scales as ratio scale measures for chronic and experimental pain. *Pain* 1983; 17: 45-56.
37. CONSOLARO A, RUPERTO N, BAZSO A *et al*.: Development and validation of a composite disease activity score for juvenile idiopathic arthritis. *Arthritis Rheum* 2009; 61: 658-66.
38. FOELDVARI I, RUPERTO N, DRESSLER F *et al*.: The German version of the Childhood Health Assessment Questionnaire (CHAQ) and the Child Health Questionnaire (CHQ). *Clin Exp Rheumatol* 2001; 19 (Suppl. 23): S71-5.
39. RASCHNER C, LEMBERT S, PLATZER H-P, PATTERSON C, HILDEN T, LUTZ M: S3-Check - evaluation and generation of normal values of a test for balance ability and postural stability. *Sportverletzung Sportschaden* 2008; 22: 100-5.
40. TILSCHER H, GRUBER D, LEMBERT S, RASCHNER C: Effects of impairments at the movement apparatus on the result of the S3-body stability test. *Manuelle Medizin* 2007; 45: 409-14.
41. RAVELLI A, CONSOLARO A, SCHIAPPAPIETRA B, MARTINI A: The conundrum of juvenile psoriatic arthritis. *Clin Exp Rheumatol* 2015; 33 (Suppl. 93): S40-S3.
42. NOLAN L, GRIGORENKO A, THORSTENSSON A: Balance control: sex and age differences in 9- to 16-year-olds. *Dev Med Child Neurol* 2005; 47: 449-54.
43. SIMONEAU M, TEASDALE N: Balance control impairment in obese individuals is caused by larger balance motor commands variability. *Gait Posture* 2015; 41: 203-8.
44. SMITH AW, ULMER FF, WONG DP: Gender differences in postural stability among children. *J Hum Kinet* 2012; 33: 25-32.
45. SOUZA FMB, MCLAUGHLIN P, PEREIRA RP *et al*.: The effects of repetitive haemarthrosis on postural balance in children with haemophilia. *Haemophilia* 2013; 19: e212-e7.
46. BOCCALANDRO E, PASTA G, MANNUCCI PM *et al*.: Integrated postural analysis in children with haemophilia. *Haemophilia* 2014; 20: 263-7.
47. MESSIER SP, GLASSER JL, ETTINGER WH JR, CRAVEN TE, MILLER ME: Declines in strength and balance in older adults with chronic knee pain: A 30-month longitudinal, observational study. *Arthritis Rheum* 2002; 47: 141-8.
48. MINDEN K: Adult outcomes of patients with juvenile idiopathic arthritis. *Horm Res* 2009; 72 (Suppl. 1): 20-5.
49. SPAMER M, GEORGI M, HAEFNER R, HAENDEL H, KOENIG M, HAAS J-P: Physiotherapy for juvenile idiopathic arthritis. *Z Rheumatol* 2012; 71: 387-95.
50. HUGLE B, HAAS J-P, BENSELER SM: Treatment preferences in juvenile idiopathis arthritis - a comparative analysis in two health care systems. *Pediatr Rheumatol Online J* 2013; 11: 3.
51. REDFERN MS, SCHUMANN T: A model of foot placement during gait. *J Biomechanics* 1994; 27: 1339-46