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Postural Control in Preschool Children with Developmental Coordination Disorder, in a Sitting Position during a Functional Task

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Dissertation to obtain the degree of:

Master of Physical Activities in Special Populations

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Tudo vale a pena se a alma não é pequena…

Everything is worth it if the soul is not small…

Fernando Pessoa

Acknowledgements

First and foremost, I would like to thank the most important people in my life, my mother, my father, and my other half. Without them, their support and unconditional love, this document would not have been possible. I can never thank you enough, Mum and Dad, for all you have done for me. I hope to make you proud of my achievements. Thank you, Ricardo, for being the best boyfriend and partner that I could ever have wished for. I would also like to thank my sister and nieces for being a source of my motivation without even realising it.

I am thankful for my brother-in-law, for all the support, affection and friendship that he extended to me, even though he is no longer among us, he continues to be a source of motivation and strength for me.

Having thanked my closest relatives, I cannot forget my “academic family”, all those who shared this journey with me. Thank you, Professor Doctor David Catela for believing in me and working with me from the first semester of the first year of my graduation until this day. Thanks for being infinitely patient with me. I cannot find a word to express all my gratitude towards all the support I received from you.

Thank you, Professor Doctor Marco Branco for being an example and role model, for all the support, patience and time dedicated to helping me. Thank you very much for everything.

Thank you, Professor Doctor Ana Arrais for sharing all the knowledge and experience, and for being a real inspiration.

I would also like to thank Professor Orlando Fernandes, who despite never having worked with me, believed in my value and accepted to be my co-advisor.

Finally, I would like to thank Professor Doctor Nicholas Stergiou for being my “distant cousin” in the nonlinear family, and for all the knowledge he has passed on to me.

Abstract

The developmental coordination disorder is a motor disorder (DCD) that affects 5-6% of school-agechildren (Vaivre-Douret, 2014). DCD children are a heterogeneous group which reveal several problems in their motor control and learning (Vaivre-Douret, 2014). Being the postural control (PC) deficit, which affects 73 to 87% (Macnab, Miller, & Polatajko, 2001) one of the most prevalent and conditioning.

The present dissertation pretends to analyse and compare PC in probable DCD (p-DCD) so as to identify new clues for a most suitable intervention. For that reason, several conditions were selected incorporating baselines, and also a functional task to bring the study closer to children's daily life (e.g. Mercê et al., 2016). P-DCD, at-risk and typical children (N=14, 3.9±0.2 years) performed the following tasks: i) remain seated; ii) idem i) with closed eyes; iii) observing the modelling of a plasticine ball; iv) moulding a plasticine ball; and v) idem iv) with closed eyes.

In order to identify p-DCD children, a MABC-2 battery test (Henderson & Sugden, 2007) was applied to 46 children (3.9±0.26 years old, 25 girls and 21 boys) of three pre-schools in Rio Maior and São João da Ribeira. 2 children were identified as having p-DCD (4.4%), 7 children as being in the risk zone (15.2%) and 37 children as having typical motor development (80.4%).

Being an idiopathic disorder which can result from various causes, namely from problems with sensory integration (Vaivre-Douret et al., 2011), the PC deficit may have an origin in their own process and the way it develops through time. To analyse PC, linear methods were used, which quantify movement, and also nonlinear methods which analyse the quality of movement and how it evolves through time (e.g. Deffeyes, Harbourne, Kyvelidou, Stuberg, & Stergiou, 2009). Data was collected by filming (240 Hz) and kinematic data (APAS) were analysed and nonlinear data, including measures of recurrence and Lyapunov (Matlab) for vertex, C7 points.

P-DCD seem to be more dependent on external stimulus like visual information to auto-organize their own balance. The greater the complexity of the task, the fewer and slower their oscillations were but also more recurrent and periodic. Probably the problem p-DCD children present is not in terms of motor control, but on perception-action cycles' effectiveness; on which stimulation should focus. Despite having oscillated more and faster in all conditions, and being tendentially more recurrent and periodic, at-risk children revealed a behaviour pattern similar to that of typical children in both points studied. The nonlinear methods can be used in PC study in DCD children, however, it's crucial to find a more suitable data collection strategy for at least 2000 data.

Keywords: children, DCD, postural control, MABC-2, functional task

Resumo

A desordem coordenativa no desenvolvimento (DCD) consiste numa desordem motora que afeta 5-6% das crianças em idade escolar (Vaivre-Douret, 2014). As crianças com DCD consistem num grupo heterogéneo as quais revelam vários problemas no controlo e aprendizagem motora (Vaivre-Douret, 2014). Um dos problemas mais prevalentes e condicionantes reside no controlo postural (CP), o qual afecta 73 a 87% (Macnab, Miller, & Polatajko, 2001).

A presente dissertação pretende analisar e comparar o CP em crianças com provável DCD (p-DCD) de forma a identificar pistas para uma intervenção mais adequada. Neste sentido, foram selecionadas várias condições incorporando *baselines* e também uma tarefa funcional de forma a aproximar o estudo da vida diária da criança (e.g. Mercê et al., 2016). Crianças com p-DCD, em risco e típicas (N=14, 3.9±0.2 anos) realizaram as seguintes tarefas: i) estar simplesmente sentado; ii) idem i) com olhos fechados; iii) observar a modulação de uma bola de plasticina; iv) moldar uma bola de plasticina; v) idem iv) com olhos fechados.

A fim de identificar as crianças p-DCD foi aplicada a bateria de testes MABC-2 (Henderson & Sugden, 2007) em 46 crianças (3.9±0.26 anos, 25 raparigas e 21 rapazes) de três pré-escolas de Rio Maior e São João da Ribeira. 2 crianças foram identificadas com p-DCD (4.4%), 7 como pertencendo a uma zona de risco (15.2%) e 37 com desenvolvimento motor típico (80.4%).

Sendo uma desordem idiopática a qual pode resultar de várias causas, nomeadamente de problemas na integração sensorial (Vaivre-Douret et al., 2011), o problema no CP pode ter origem no seu processo e na forma de como este evolui ao longo do tempo. Para analisar o CP foram utilizados métodos lineares que quantificam o movimento, mas também métodos não lineares os quais analisam a qualidade do movimento e a forma de como este evolui (e.g. Deffeyes, Harbourne, Kyvelidou, et al., 2009). Os dados foram recolhidos através de filmagem (240 hertz) e foi realizada análise cinemática (APAS) e não linear incluindo medidas de recorrência e Lyapunov (Matlab) para os pontos vértex e C7.

As crianças com p-DCD parecem ser mais dependentes dos estímulos exteriores como a informação visual para auto organizarem o seu controlo postural. Quanto maior a dificuldade da tarefa, menores e mais lentas foram as oscilações, tendo sido também mais recorrentes e periódicas. Provavelmente o problema das crianças com p-DCD não está no modo de como controlam a sua postura, mas na eficácia nos ciclos de perceção-ação, devendo a estimulação focar esse aspeto. Apesar de oscilarem mais e mais rápido em todas as condições e serem tendencialmente mais recorrentes e periódicas, as crianças em risco revelaram um padrão de comportamento similar às típicas para os dois pontos em estudo. Os métodos não lineares podem ser utilizados no estudo do CP em crianças com p-DCD, contudo é crucial encontrar uma estratégia adequada de recolha de dados que permite obter pelo menos 2000 dados.

Palavras-chave: criança, DCD, controlo postural, MABC-2, tarefa funcional

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List of Abbreviations

AA – articulation task

A-AP - amplitude in anterior-posterior direction

AC - auditory–choice reaction task

ADHD - attention-deficit-hyperactivity disorder

AM - auditory–memory task

Ao - area of sway

AP - anterior-posterior

APAS - Ariel Performance Analysis System

ApEn - approximate entropy

AV - auditory–verbal reaction task

BPM - balance performance monitor

C7 - cervical 7

CDP - computerized dynamic posturography

COP - centre of pressure

CP - cerebral palsy

DD - developmental delay

DEO - do with eyes open

DEC - do with eyes closed

%DET - determinism percentage

DCD - developmental coordination disorder

DCD-BP - children with DCD and balance problems

DSM or DSM-MD - Diagnostic and Statistical Manual of Mental Disorders

ES - equilibrium score

EMG - electromyography

IQ - intelligence coefficient

HD - high difficulty

L - path length

Lat - medio-lateral sway

LD - low difficulty

LOS - limit of stability

LyE - Lyapunov exponent

ML - medio-lateral

MV-AP - mean velocity in anterior-posterior direction

OC - counting task

PC - postural control

p-DCD - probable DCD

R – at-risk children

RDCD - children at risk of DCD

%REC - recurrence percentage

%RECUR - recurrence percentage

RQA - recurrence quantification analysis

SD - see doing

SEC - sitting with eyes closed

SEO - sitting with eyes open

SOT - sensory organization test

SPSS - Statistical Package for Social Sciences

T - typical children

TD-AP - total distance in anterior-posterior direction

TD - typical development

TDC - typical developmental children

SampEn - sample entropy

VI - visual information

V - vertex

Vmax - biggest length of vertical lines

X - frontal plan

Y - transverse plan

Z - sagittal plan

Chapter I

Introduction and Conceptual Framework

1. Introduction

The present dissertation is organized into chapters, chapter I is related to the dissertation's organization, an introduction to the theme and a conceptual framework. Chapter II consists of a systematic review of postural control in DCD children. Chapter III describes the application and results from the MABC-2 application. Chapter IV describes the balance study in DCD children with linear and nonlinear methods. And, finally, Chapter V consists of the general conclusions and recommendations. In the final, we can also find the data and the appendixes.

The developmental coordination disorder (DCD) is a motor disorder that affects, at a very early age, the Motoricity and daily life of children (Vaivre-Douret, 2014). The inexistence of intellectual, neural and other severe health complications makes it possible for the sports graduated to intervene with these children. So, DCD is in this way another possible field of activity for professionals in the movement sciences area, and, personally, I find it a more gratifying one.

One of the most common problems in DCD, and probably one of the most conditioning factors is postural control deficit (Macnab, Miller, & Polatajko, 2001). The poor balance control affects all the children's activities and can keep them away from body activities, like sports and dance (Oudenampsen et al., 2013; Poulsen, Ziviani, Cuskelly, & Smith, 2007). So, these are an important area to study and to work on with this type of population.

Despite all the investigations already conducted on the aethology of DCD is still not clear, several hypotheses were proposed, including a sensory integration problem (Vaivre-Douret et al., 2011). If this is true the DCD problems, namely the PC deficit could have a cause in its own process. In order to analyse PC, tools and methodologies, which not only evaluate the quantity of movement, but also the quality of it and how it evolves through time, should be considered.

Nonlinear methods like recurrence analysis or a Lyapunov exponent can analyse the data evolution and not only the final result. Already used in motor disorders like cerebral palsy (e.g. Deffeyes, Harbourne, Kyvelidou, Stuberg, & Stergiou, 2009), these methods proved to be sensitive to small postural adjustments and even to identify significant differences between children with motor disorders and typical children.

In this way, in the present research, we pretend to analyse and study postural control in children with p-DCD, at-risk and typical children undergoing a functional task, by using linear and nonlinear methods.

2. Conceptual Framework

2.1. Developmental Coordination Disorder

The developmental coordination disorder (DCD) is a motor disorder identified and recognized by the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013). This disorder is expressed early in life, affecting 5-6% of school-aged children (Vaivre-Douret, 2014; Vaivre-Douret et al., 2011). The children with DCD reveal several developmental problems in their fine and global motor coordination, difficulties in motor control and learning, and in the acquisition of new motor skills (Vaivre-Douret, 2014) (see table 1).

Usually named as “clumsy” or “poorly coordinated”, these children display real difficulties in motor control and learning, which are expressed in many ways, such as a delay in achieving motor milestones, clumsiness, poor balance, difficulties in writing and drawing (Chang & Yu, 2010), poor postural control (Geuze, 2005), difficulties in space and temporal organization (Wilson & McKenzie, 1998), see Table 1.

Simple motor tasks can present a problem for DCD children, they may have difficulty in dressing and undressing themselves, tying their shoelaces, controlling their position and forcing an object to move, drawing pictures, or simply jumping or running with a friend.

DCD children are a heterogeneous group, as they can reveal only part of the symptoms rather than all simultaneously, e.g., the child may reveal balance problems but no visual and spatial difficulties, and vice versa (Vaivre-Douret et al., 2011). One of the most prevalent problems is the postural control deficit, which affects 73 to 87% of the DCD children (Macnab, Miller, & Polatajko, 2001). The postural control problem is also one of the most conditioning factors, since it is crucial for all daily tasks such as walking, running, playing, putting groceries on a shelf, picking something up from the ground, reacting to an unexpected disturbance like avoiding an obstacle such as a bike, and so on. .

All of that affects the daily life of the children (Van der Linde et al., 2015) and, consequently, brings on more challenges and new ordeals, such as academic delay or social isolation (Joshi et al., 2015; Vaivre-Douret, 2014). A child who manifests an increased difficulty in coordinating his/her own body in position, time and force, with the environment, will probably be a child with fewer skills in dribbling a ball, running faster, shooting the ball to the goal, avoiding the other team’s player, and so on. Consequently, this sort of children, DCD children, display a tendency to avoid sports activities. Normally, they are less involved in physical activity, tend to have sedentary behaviours and poorer fitness, compared to the typical children within the same age group (Magalhães, Cardoso, & Missiuna, 2011; Poulsen et al., 2007). This behaviour conducts them to social isolation, with an increase in psychological issues, like anxiety and depression (Caçola, 2016). DCD children, with and without balance problems, revealed to have significantly higher obesity prevalence than typical children (Cermak et al., 2015).

The difficulties in motor control and learning affect not only the "children motor part" but the child, additionally, they have a cascade effect leading to isolation, inactivity, discouragement, and metabolic disorders like obesity. For all of this and facing physical and psychological complications, DCD is considered to be one of the major health predicaments among school-aged children worldwide (Caçola, 2016).

Unfortunately, DCD does not simply disappear as time goes by, the disorder remains throughout puberty and adult life (Cousins & Smyth, 2003a). An early diagnosis accompanied by an early intervention may help reduce the negative effects of DCD and also provide a better quality of life for these children now and later on in their adult life (Smits-Engelsman et al., 2013).

Table 1 – Synthesis of difficulties and characteristics of DCD with study examples

Difficulties and Characteristics	Literature (examples)
Fine and global motor coordination	(Harris, Mickelson, & Zwicker, 2015; Smits-Engelsman, Wilson, Westenberg, & Duysens, 2003)
Motor control and learning	(Caçola, 2014; Jelsma, Ferguson, Smits-Engelsman, & Geuze, 2015)
Acquisition of new motor skills	(Vaivre-Douret, 2014; Vaivre-Douret et al., 2011)
Delay in motor milestones	(Harris et al., 2015; Kirby & Sugden, 2007)
Poor balance / balance control	(Geuze, 2005; Macnab et al., 2001a)
Drawing and writing	(Chang & Yu, 2010; Prunty, Barnett, Wilmut, & Plumb, 2016)
Space and temporal organization	(Fernani et al., 2013; P. H. Wilson & McKenzie, 1998a)
Academic delay	(Gibbs, Appleton, & Appleton, 2007; Van der Linde et al., 2015)
Less sports practice	(Cairney et al., 2005; Oudenampsen et al., 2013)

Social isolation	(Piek, Barrett, Allen, Jones, & Louise, 2005; Poulsen et al., 2007)
Mental health problems (e.g. anxiety and depression)	(Kristensen & Torgersen, 2008; Lingam et al., 2012)
Low self-esteem	(Cairney, 2015; Piek et al., 2005)
Overweight and obesity	(Cermak et al., 2015; Zhu et al., 2014)

2.1.1. Etiology

Despite the research and the various theories, DCD aetiology is still unclear (Missiuna, Gaines, Soucie, & McLean, 2006). Until recently, it was considered that DCD just affected children, nowadays we know that this is not true and that DCD affects adolescents and adults alike (Cousins & Smyth, 2003; Vaivre-Douret, 2014). The characteristic difficulties of DCD can vary in severity, between children, and in the child through time (Barnett, 2008) however, when the disorder is present it becomes chronic.

DCD is an idiopathic disorder that can result from various causes, being independent of sex, race, culture, economic or academic status. It is a chronic disorder that can vary in nature and severity (Vaivre-Douret, 2014).

In literature, it is reported a probable association with prematurity and low weight to DCD (Edwards et al., 2011; Zhu, Olsen, & Olesen, 2012). It is also suggested several other probable causes, such as a problem in the maturation of central nervous system, prematurity, a dominant cerebral hemisphere, problems with sensory integration, perinatal factors like anoxia and hypoxia (Vaivre-Douret et al., 2011).

Recently, the search suggested that the cause could reside in a cerebellum problem as this is crucial in developing automatic movement control, and, also, in monitoring the movement during the time; and, both these functions are affected in DCD children (CanChild, 2016).

One of the difficulties encountered in the discovery of DCD cause, is the presence of comorbidities; frequently, DCD children do not suffer solely from this disorder (Cairney, 2015).

2.1.2. Comorbidity

The Diagnostic and Statistical Manual of Mental Disorders V (DSM) define DCD as a motor disorder without any medical condition, presenting it as a single disorder. However, as in other motor disorders, in DCD, the comorbidity is the rule and not the exception (Cairney, 2015); it is more common to find a DCD child showing signs of other disorders simultaneously rather than DCD alone.

Some examples of comorbidity are dyslexia (Kirby & Sugden, 2007), specific language issues (Hill & Bishop, 1998), attention deficit (Landgren, Kjellman, & Gillberg, 1998), attention-deficit-hyperactivity disorder (ADHD) (Watemberg, Waiserberg, Zuk, & Lerman-Sagie, 2007), autism (Piek & Dyck, 2004), Asperger (SECronoff, Leslie, & Brown, 2004), or, epilepsy (Cairney, 2015). The most prevalent comorbidity is ADHD, with a rate of close to 50% (Watemberg et al., 2007).

Some of the comorbidities are so closely related to DCD that they seem to belong to this disorder and do not appear to be an independent disorder. The association between disorders make a suitable identification of DCD more complicated and, in some cases, delay it.

Children exhibiting DCD and other neurodevelopmental disorders simultaneously, like attention-deficit-hyperactivity disorder (ADHD) for example, revealed poorer function and health outcomes than did children portraying one of the disorders (Missiuna et al., 2014). This should alert us to the importance of comorbidity identification, and the need to adjust and possibly enforce our intervention.

2.1.3. Diagnostic

DCD is present in the first years of life, however, it is often diagnosed after the child reaches 5 years of age (Kirby & Sugden, 2007).

According to the European Academy of Childhood Disability, DCD should be diagnosed by a multidisciplinary team of professionals qualified to examine the specific criteria for the disorder (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012).

In ideal conditions, the team should include a physician, like a child psychiatrist or neurologist, and an occupational therapist or physical therapist trained in the standardized motor tools used to assess the disorder (Harris et al., 2015).

To diagnose DCD, some **criteria** have to be respected (Blank et al., 2012; Harris et al., 2015):

- The acquisition and execution of coordinated motor skills are substantially below what would be expected for its chronological age, the children can also show slowness and inaccuracy in performing motor skills (e.g. making beads bracelets, threading beads on a string, catching an object, or participating in sports).

To access this criteria the motor test most widely used is the Movement Assessment Battery for Children, second edition (MABC-2) (Henderson & Sugden, 2007; Kirby, Sugden, & Purcell, 2014).

- The motor skills deficit greatly and persistently interferes with activities of daily living suited to the chronological age as does it affect academic/school productivity, prevocational and vocational activities, leisure and play (e.g. dressing, tying shoelaces, brushing teeth).

To access this criteria, parents and teachers can use checklists such as the Developmental Coordination Disorder Questionnaire (Wilson et al., 2009) or the MABC-2 checklist.

- The symptoms are revealed early.

To access this criteria parents may be questioned about their child's developmental history and milestones, however, some children do not show delayed motor milestones.

- Motor skills deficits are neither explained by intellectual disability or visual impairment nor are they attributed to a neurologic condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder).

To access these criteria children should take an IQ test by a psychologist, a formal IQ assessment may not be necessary if there has been a typical achievement at school. A neurologist test is also relevant to exclude impaired motor development, as is a visual test to exclude visual impairment.

The batteries acknowledged in literature as valid and suitable to determine and help diagnose DCD are the Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2) (Bruininks & Bruininks, 2005), and MABC-2 (Henderson & Sugden, 2007), being the latter, the most used worldwide.

The MABC-2 consists of a battery test that enables the identification and description of the motor impairment in children. It is divided into three age bands; band 1- 3 to 6, band 2- 7 to 10 and band 3- 11 to 16 years of age.

Each band is composed of tests in three categories, manual dexterity (3 tests), aiming and catching (2 test), and static and dynamic balance (3 tests). The battery classification works like traffic lights with 3 zones, by scoring the tests, MABC-2 determines whether the child is in the: red zone - with a probable DCD (p-DCD); orange zone - at risk of developing DCD; or, green zone -a typical zone. It is important to note that in order to diagnose DCD, the four criteria explained above have to be present, if this does not occur we can simply refer a probable DCD. The orange zone is a transition zone in which the child does not possess the disorder but displays motor impairments, so he/she is considered to be at risk of developing DCD. The red zone, p-

DCD, corresponds to a total score of equal or less than percentile 5; the orange zone, at- risk, to equal or less than percentile 16; and the green zone, typical, to a total score higher than percentile 16. Apart from the division and classification in the 3 zones, the percentile score allows us to assess the severity of the disorder. The lower the percentile the higher the severity.

In addition to the total score, the battery also classifies motor performance by category, so we can find children with p-DCD but with a risk classification in one or more categories, e.g., a child may have a typical total score, and reveal a risk score in manual dexterity.

The possibility to discriminate the categories where the children have motor impairments is a strong point of MABC-2. As shown above, DCD children are a heterogeneous group and may reveal just part of the symptoms, rather than all simultaneously (Vaivre-Douret et al., 2011).

2.2. Dynamic Systems

The theoretical model that supports data analysis in this dissertation is dynamic systems (Kelso, 1995). From this perspective, the human movement system results from a highly complex network of subsystems that co-depend on each other (e.g. musculoskeletal, nervous, circulatory, respiratory, proprioceptive). Thus, subsystems are also composed of various interacting components that together makes the movement possible (e.g. molecules, bones, muscle tissue, enzymes, blood cells). Regardless the task, to develop the system motor abilities capacity, composed by all the subsystems and the interacting components, explore degrees of freedom (Glazier, Davids, & Bartlett, 2003).

In dynamic systems, movement patterns emerge from self-organization between physical and biological systems (Glazier et al., 2003; Kelso, 1995). Despite carrying a common term, the pattern concept is difficult to explain. When we think of the pattern we should redirect our attention not to things themselves, but to the relation between them. It's easier to imagine and see a pattern than it is to explain it, like butterfly wings, the silk threads of the spiderweb, the snail shell format or honeycombs. So, we can consider a pattern like a combination of qualities, acts, tendencies forming a consistent or a characteristic arrangement (Kelso, 1995).

Self-organization simply means that the system organizes itself; however, the self as an entity does not really exist, no one is inside the system making it work. Inside it, billions of molecules and atoms that compose all the subsystems, and other levels of connections, like synapses and reflexes, afford communication and self-organizing for movement to emerge.

According to dynamic systems theory, during the motor development the coordination improves, and movements become more specific and adjusted. This coordination improvement dramatically reduces the number of biomechanical degrees of freedom of the motor system needed to produce adjusted movements; with practice, the system becomes more and more economic and efficient (Turvey, 1990). The reduction of complexity and more coordinated and efficient movements enhances the system to develop functionally preferred modes of coordination, sometimes referred to as attractors, the system is attracted to behave in that kind of mode.

An attractor is a stable zone which has three characteristics: magnetic effect, leading the system to a preferred zone; stability, in this zone we can observe a decrease in variability of the kinematic variables; and, critical limits, between stable phases. In sum, when a system stays in an attractor it is highly ordered and stable inside the attractor zone. However, the instability between attractor regions also permits a more flexible and adaptive response of motor system behaviour, leading to a higher exploration, and, in some cases, a better performance (Glazier et al., 2003).

Inside the theoretical model of dynamical systems, considering a system that evolves over time, we can find linear and nonlinear states; and, in nonlinear states we also can find chaotic states (Figure 1). Although we may think that something chaotic is something bad and highly messy, a chaotic system is a deterministic system that is aperiodic, sensitive and dependent on the initial conditions and bounded. In a simpler manner, in a chaotic system, we can find some strange irregular fluctuations that, at first glance, we will probably think is just noise; but, with a deeper analysis, we will find hidden patterns that result from its complex nonlinearity.

All system behaviours are affected by the initial conditions; what happens is related to what has happened before, and with what will happen next. Therefore, attractors happen; attractors are revisited spaces by the system because past, present and future are intrinsically connected.

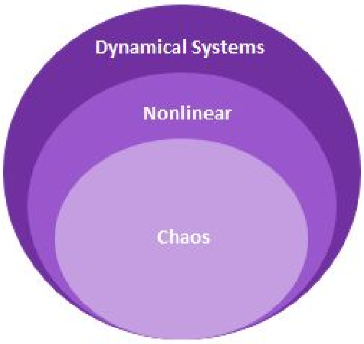
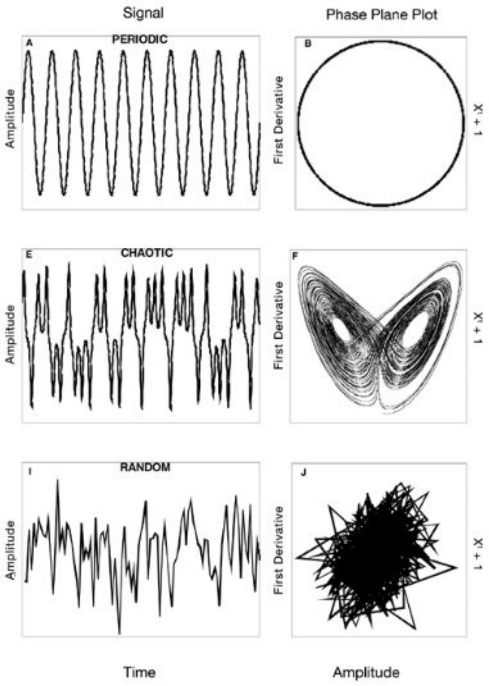


Figure 1 – Relation between dynamic systems, nonlinear and chaos

To talk about dynamic systems and chaos is to talk about the concepts of variability and complexity. The variability concept is another one that is simpler to imagine and understand through examples than trying to explain it. Variability is a fact of life, it is always around us and follows us everywhere. Imagine the best sniper in all history, if we ask him to shoot at a target a thousand times, he will probably always hit the centre of the target. But will he shoot exactly in the same place? The answer is no; despite seeing a stain in the target we will sometimes shoot a millimetre up or down, right or left. Take the example of your eyes, if you stare at an object, are your eyes steady? No. Were they still, after a while you would stop seeing the object. Another example, when you are standing on one foot, can you remain totally static? No. If you tried to, you would fall. We need to be unstable (within some limits, the limits of the attractor) to stay in tune. Variability ensures the system to have continuous references, without having a fixed, defined reference. This is the way all systems behave (except old computers). What we mean by this is that the variability not only is always present, but also is necessary. This need is the basis of Bernstein's (1967) proposition: repetition without repetition. This way of functioning is essential because initial conditions are always changing, inside and outside the system, because all systems are continuously evolving, it is the arrow of time. We walk millions of steps during our life, we are experts at walking; but do we take two steps in exactly the same way? No, we will make some adaptations in speed and positions, according to our age, the place and the moment when we are walking. We can define variability as an inherent variable within our motor (dynamical) system, resulting in normal variations across repetitions of a task (Stergiou, 2004).

The complexity is defined through high fluctuations in system behaviour that resemble mathematical chaos (Stergiou, 2004; Stergiou, Harbourne, & Cavanaugh, 2006). The more and more different the fluctuations, the greater the complexity. To better understand these concepts, we can observe in Figure 2, examples of a periodic signal, a chaotic signal (the Lorenz Attractor) and a random signal. In true random time series, no pattern is present, all data are completely aleatory.



Periodic (Sine Wave)

- ✓ High predictability
- ✓ Low variability
- ✓ Low complexity

Chaotic (Lorenz Attractor)

- ✓ Less predictability
- ✓ High complexity

Random

- ✓ Very low predictability
- ✓ High variability
- ✓ Low complexity

Figure 2 – Examples of periodic, chaotic and random signal (adapted from Stergiou, Harbourne, & Cavanaugh, 2006)

Considering the theoretical model and the concepts of dynamical systems presented; we hope to prove that the children with probable DCD could be considered as a dynamic system, that is sensitive to initial conditions, and that, these can afford them to evolve less predictable and more complex attractors; meaning that they have the capability to adapt to and solve motor problems, probably, enticing them to explore new and more adjusted modes of motor action.

2.3. Postural Control

The postural control system plays two main roles: the first refers to the maintenance of balance against gravity; and the second consists of the interface of perception and action with the external world, where the position and orientation of the body segments serve as an anchor to adjust and adapt the movement (Massion, 1994). So, postural control or balance control is essential to posture and locomotion (Assaiante & Amblard, 1995). In biomechanics, we can also define that postural control occurs when the centre of body mass is kept inside the supporting base, the area produced by the exterior delimitation of the support points; when pulled outside of those frontiers the system imbalances (Mittelstaedt, 1983).

This double function is only possible due to a complex system that is based on four components: reference values, like the orientation of body segments and position of the gravity's centre; multisensory system; and, flexible postural reactions that permit the system to recover after a disturbance, or maintain its posture during voluntary movements (Massion, 1994).

The central organization of posture involves interactions between external forces, like gravity, mechanical properties of the body and neuromuscular forces. To control posture, the system must control the whole body, all the segments, muscles and joints which bring together a huge multiplicity and variety of freedom degrees (Hadders-Algra, 2005).

As in a dynamical system, postural control is affected by the initial conditions. To keep my balance or to do some task I will be conditioned by external factors, and by the successive results amid my balance and those external constraints, defining the sequence of past, present and future postural adjustments, during task execution.

2.3.1. The sensorimotor organization of balance control in healthy children

The various balance patterns observed in adults and children involve two functional principles (Assaiante, 1998; Assaiante & Amblard, 1995). As mentioned before postural control is dependent on reference values (Massion, 1994). So, the first principle consists of the choice of the reference frame on which postural control is based. This could be the supporting base or the gravitational vector. When the reference frame consists of the supporting base, the balance control is temporally organized from the feet to the head according to an ascending organization. When the reference frame consists of the gravitational vector the balance control is organized from the head to the feet according to a descendent organization (Assaiante &

Amblard, 1995). In special cases, during an intermittent contact like locomotion, it is also possible that the reference frame becomes another anatomic segment like the pelvis for instance (Assaiante, 1998). The choice of the reference frame depends on the dynamic constraints and the difficulty of the posture or the task.

The second functional principle is based on degrees of freedom, the body segments and joints, which must be controlled and co-work together to maintain the posture or do the task. The degrees of freedom will depend on the dynamic constraints, the systems' (subjects) characteristics and their abilities. The control of the composite head-trunk unit can occur according to two main modes (Assaiante, 1998; Assaiante & Amblard, 1995). Firstly, the head could be stabilized on the trunk by the neck muscles' contraction, as mentioned in the "strap-down strategy" or "en bloc" mode. This mode minimizes the degrees of freedom during movement and allows more direct and rapid visual and vestibular contribution to balance control. Secondly, the head-trunk could be stabilized with the neck structures loose in space, also called "stable platform strategy" or "articulated operation". This second mode allows more degrees of freedom in the neck joints, and makes it indispensable to take into account the position of the head and trunk, for the use of visual and vestibular information in postural control. This "en bloc mode" and "articulated mode" could be extended to a couple of other consecutive anatomical segments and not only to the head-trunk unit.

2.3.2. Balance evolution in life span

According to the principles and balance modes mentioned before, Assaiante and Amblard (1995) proposed an ontogenetic model of balance control developing during life span. The authors considered two main modes of balance control, ascending and descending organization, which operate alternately, and are associated with the two modes of join link, "en bloc mode" or "articulated mode". This evolution occurs during four periods (Figure 3).

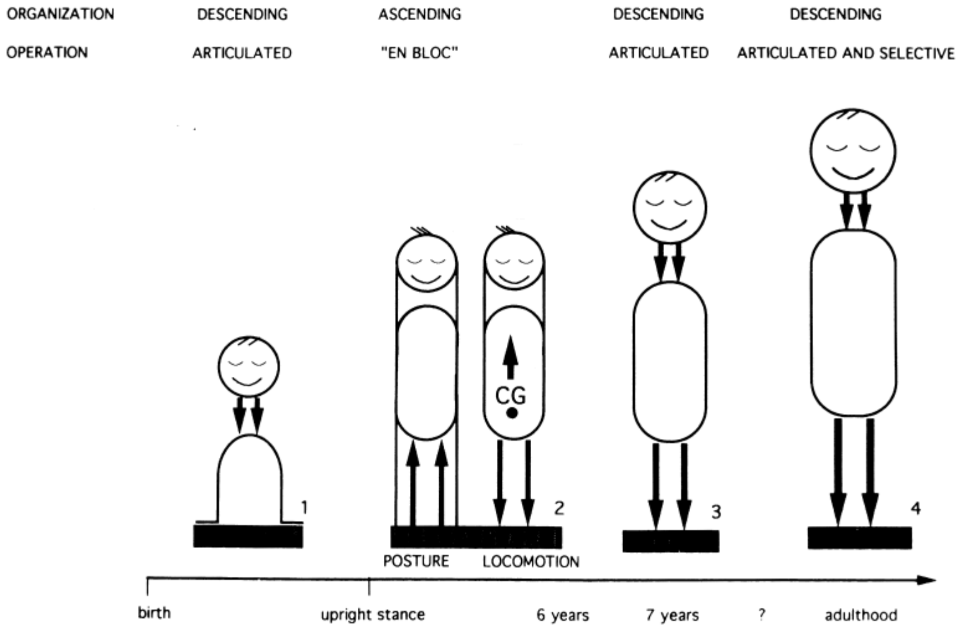


Figure 3 – Ontogenetic model of balance control developing (retrieved from Assaiante, 1998)

The first period is referred from birth to the acquisition of an upright position, control is developed first in neck muscles, then in the trunk and finally in the legs, respecting a top-down recruitment with a descending temporal organization. With the conquest of the upright position and locomotion, the balance control passes from segmental to global and a new period begins.

The second period begins in an upright position to around 6 years of age. During this period a development of coordination occurs between lower and upper body, concurrently with the maturation of the postural control system, e.g., cerebellum and vestibular system.

The third period begins at 6-7 years and has no defined limit yet. During adolescence a descending temporal organization with an articulated mode of head-trunk operation is present.

Finally, the fourth period is related to adult life. Postural control continues to proceed in a descending temporal organization, with an improvement, the articulated operation of head-trunk unit goes on to be made in a selective control of degrees of freedom at neck level.

2.3.3. Sensory contributions for postural control

As mentioned before, the multisensory system is an important part of the postural control system (Massion, 1994), contributing with three kinds of inputs: visual, vestibular and somatosensory inputs (Assaiante, 1998). Depending on the dynamical constraints of the subject, child or adult, the use of these inputs has different combinations. Despite not yet having been proven that visual input is the prominent one that established postural control during infancy, it was proven that it predominates during transitional periods, when infants try to accomplish postural challenges, such as sitting up, acquiring the upright position or walking independently (Assaiante, 1998).

For posture maintenance, the visual predominance is not restricted to infancy and continues up to about 6 years of age (Assaiante & Amblard, 1992) and locomotion (Shumway-Cook & Woollacott, 1985). For postural control, the peripheral visual contribution increases from 3 to 6 years, and becomes maximal around 6 years of age (Assaiante & Amblard, 1992). At age 7 the vestibular contribution becomes more prominent. In adult life, all three kinds of inputs can be coordinated and used to improve balance.

2.3.4. Postural control measurements

Postural control can be studied using different methods, including linear and nonlinear ones. The linear or also called traditional methods, proved to be interesting to provide information about postural control in children (e.g. Rival, Ceyte, & Olivier, 2005). Some examples of linear methods are the displacement or speed of the centre of pressure (COP), which consist of the point of application of the ground reaction force; amplitude, displacements and velocity for each movement plan; or, the area of the displacement for each movement plan or in the three dimensions.

These traditional methods, provide us data which can be very limited in the understanding of patterns or modes of postural control (Massion, 1994), they are very descriptive of the product but not of the process.

New nonlinear methods are emerging based on the dynamic approach that intend to identify attractors in postural sway (e.g. Deffeyes, Harbourne, DeJong, et al., 2009; Deffeyes, Harbourne, Kyvelidou, et al., 2009; Harbourne & Stergiou, 2009). These methods try to detect patterns and modes of behaviour, focusing on the process, particularly when the system is unstable or in transition between two modes of behaviour.

2.4. Nonlinear Methods

One of the most used non-linear method is recurrence quantification analysis or RQA, this is a non-linear and multidimensional technique that reconstructs the temporal series in space to verify recurrent points, points that are closer to each other, also known as neighbour points. The basis of this analysis consists of rebuilding a sphere of radius *r* centred on a point *x(i)* in the reconstructed space, and counting the points that fall inside the radius. If the distance between the point and the sphere's centre is less or equal to the radius, the point will be considered recurrent (Riley, Balasubramaniam, & Turvey, 1999).

Contrary to linear methods that only provide result outcomes, the RQA allows us to process outcomes, that enable the study of dynamic systems over time and how these behave in the process (Webber & Zbilut, 2005).

This technique provides us with several variables that can describe the system, allowing its analysis, they are: i) percent recurrence (%RECUR or %REC) – percentage of recurrent points, points that fall in the radius; ii) percent determinism (%DET) – percentage of points that form diagonal lines, these diagonals indicate that the system is revisited the same region of the attractor, %DET reflect the degree of determinism; iii) maxline – the biggest length of the diagonal lines, this is a measurement of the global stability; iv) meanline – mean of the diagonal lengths, a bigger meanline implies that the system, in mean, enters in longer deterministic states; so, meanline is a measurement of periodicity; iv) entropy – a measurement of the complexity system; the higher the entropy, the higher the complexity; v) relative entropy – a measurement that reduces the influence of the length differences in the calculation of entropy, it is a measurement of difference statics between the distributions; vi) trend – measurement of the stationarity[1] of the system, values of zero or closed (± 5) indicates stationarity, while superior values indicate a drift in the system (Riley et al., 1999; Webber & Zbilut, 2005).

RQA consists of a recent technique that allows a deeper analysis into dynamic systems, namely in children during the execution of a task (e.g. Mercê, Santos, Branco, & Catela, 2013).

The vertical and diagonal lines confirm a deterministic and nonlinear system; in a simpler way, to form these lines the system's orbit in phase space will revisit the same region once and once again, allowing the detection of attractors (Palmieri & Fiore, 2009). The laminarity evaluates the amount of recurrent points that form vertical lines, evidence of laminar phases in the system, identified as intermittency. A system with higher laminarity is a more interment

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[1] **Stationarity** - in a stationary system the mean and the variance doesn't change as a function of time along the time series.

system, which means that it jumps alternately between two or more modes of behaviour, between two or more attractors. The laminarity evaluates the amount of recurrent points which form vertical lines. These lines, vertical or diagonal evidence a determinist and nonlinear system in a simpler manner, to form lines the system's orbit in phase space revisiting the same region recurrently, therefore, it is revisiting an attractor (Palmieri & Fiore, 2009). This way, the laminarity evaluated the amount of vertical lines to understand the intermittency of the system, a system with a higher laminarity is a more interment system. According to maxline to diagonal lines. We can estimate Vmax as the biggest length of vertical lines.

The Lyapunov exponent (LyE) is also one of the most popular nonlinear methods used. It detects the presence of chaos in the system. According to the chaos theory, LyE is a bounded measurement, sensitive to the initial conditions. This variable measures the rate of how nearly orbits converge or diverge in the state space (Figure 4). If the points diverge rapidly, they produce instability in the system. In periodic signals, this instability does not exist; imagine a sinewave signal, in this case the orbits will not diverge or converge so the LyE would be 0 because the trajectories in the state space are completely overlapped. If the orbits diverge the system is exploring an exponential growth, and the LyE would be superior to 0. A positive LyE indicates chaos in the system, the larger the LyE, the bigger the instability. If the orbits converge the system will reveal an exponential decay, and the LyE would be lesser than 0 (Harbourne & Stergiou, 2003).

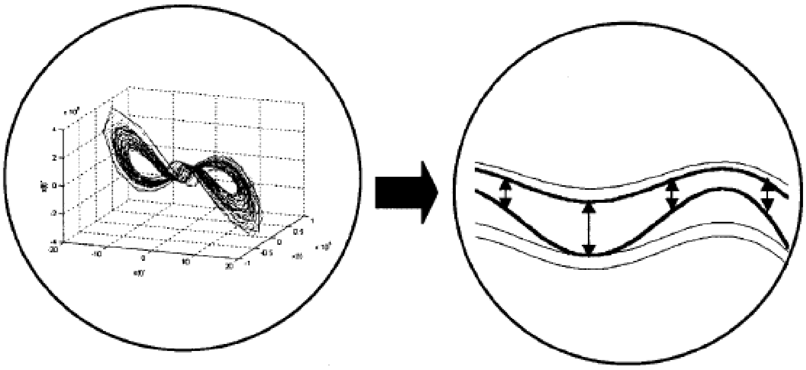

Figure 4 – Example of the lyapunov exponent (adapted from Harbourne & Stergiou, 2003)

The LyE calculation is often related to an entropy measurement, normally approximate entropy (ApEn) or sample entropy (SampEn). The ApEn quantifies the tendency of the system to visit a number of different states, in other words, ApEn measures the unpredictability of the fluctuations in a time series (Pincus, 1991). So, a random time series that is very unpredictable and does not reveal patterns, will have a large ApEn. On the other hand, in a predictable and regular time series, e.g. a sinewave, the complexity will be less and ApEn will be smaller. A change in complexity may indicate learning or a reorganization of the available degrees of freedom (Harbourne & Stergiou, 2003). Despite being used in chaotic systems, ApEn does not indicate deterministic chaos in the system, only if the data are predictable or not, being that a lower ApEn means more predictability or regularity (Pincus & Goldberger, 1994).

However, ApEn reveals some limitations, such as a dependence on data length and a lack of relative consistency. In order to overcome these limitations, the SampEn (Richman & Moorman, 2000) was developed. This is like an improvement to ApEn; so, if possible, we should prefer SampEn to ApEn. For a correct function of SampEn, the data should be larger than 200; the longer the better, and we can't compare time series with different lengths (Yentes et al., 2013).

Considering the importance of the presented methods, we intend to use linear and nonlinear methods to study postural control in children with probable DCD.

2.5. State of Art

One of the most common problems in DCD, and probably one of the most conditioning factors, is postural control deficit or balance problems (Macnab et al., 2001a). Recognizing the importance of postural control and its implications in children’s lives, this theme has been studied in DCD children.

Geuze (2003) studied the static balance in DCD children with balance problems (DCD-BP). The author evaluated 24 DCD-BP children and 24 corresponding typical children, from 6 to 12 years. Three different experiments were carried out, in the first one the children stood on one and two legs, on a force platform for 20 seconds, with their eyes open and afterwards closed, to allow the calculation of the excursion of the centre of pressure. In the second experiment, electromyography (EMG) was measured for muscles around the ankle including tibialis anterior and peroneus longus, also for muscles involved in the knee and hip joint including rectus femoris and semitendinosus, while children stood on one leg. In the third experiment, concerning a subgroup of DCD-BP and matching pairs, an unexpected force was applied on the back during the upright stance, so as to analyse balance recovery. The force was produced by a ball of 0.5 Kg tossed in a way that it almost touched the gravity centre of the child, making a perturbation in balance control, in 7 trials. As expected, the static balance improves with age for all groups studied. DCD-BP children revealed for both, two legs and one leg balance a significantly larger excursion of COP in all directions than compared to typical children. These larger COP excursions also increase when visual information is removed in DCD-BP children. Large COP values may indicate less efficient balance control. In this case, DCD-BP children revealed more difficulty in keeping their balance, specially, on one leg when visual information was retrieved. When standing on their non-preferred leg DCD-BP children revealed a bigger co-activation of the leg, suggesting an attempt to reduce degrees of freedom. When submitted to the perturbation, all children revealed a longer recovery in the first trial; and, apparently, DCD children could learn to compensate the perturbation as well as the typical children.

Chen, Tsai and Wu (2014) studied postural control in children at risk of DCD (RDCD) and typical children, based on their difficulties in judging affordances[2], essentially, what the relationship between postural sway and affordance’s perceptions was . The MABC-2 was applied to identify RDCD and typical children. RDCD were those with a total percentile score inferior to

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[2] **Affordance –** potential opportunities for motor behaviour given by the environment (Gibson, 2014).

5, and typical children with one higher than 50. Children had an IQ (intelligence coefficient) above 80, and no other detected disorder. The children were matched by age, body weight and height, and IQ. The sample was composed of 56 children, with a mean age of 11.55±.53 for RDCD and 11.68±.61 for typical ones. The children were asked to make a series of judgments about their maximum sitting height, while standing and seeing a chair moving up or down (alternately). The children should say "stop", or could ask to move it farther up or down, to adjust the position of the chair. This experiment was made with and without a 10 cm block under the children's feet. Once the final judgment occurred the duration was calculated, beginning from "ready, go" to the child's "stop", for 12 trials.

It was found that RDCD children swayed more during judgment sessions (a bigger range of anterior-posterior movements) and made less accurate judgments (Figure 5); typical children reduced their postural sway between judgments and during judgments with and without blocks under their feet, while RDCD didn't change their postural sway (Figure 6); and, typical children (TDC) modulated their postural sway of the head in the anterior-posterior (AP) axis across the trials, indicating a learning effect at the same time, however RDCD didn't reveal this adjustment, suggesting that they didn't have this learning effect (Figure 7).

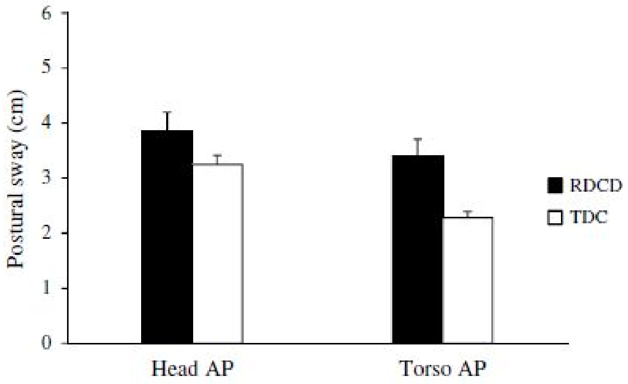

Figure 5 – Mean postural sway for anterior-posterior movements for the head and torso of the RDCD and TDC (adapted from Chen et al., 2014).

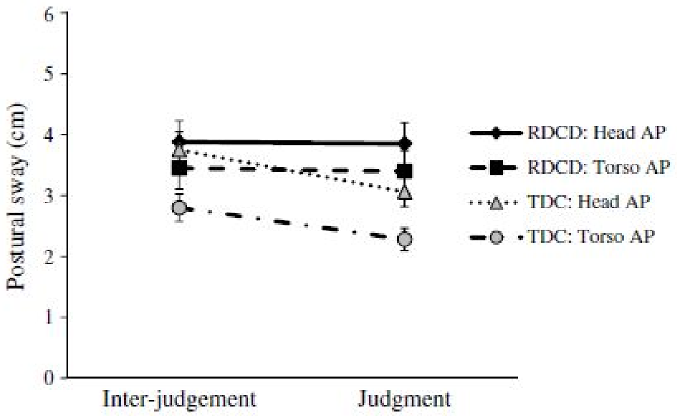

Figure 6 – Mean postural sway in AP axis for the head and torso during time inter-judgement and during judgments (retrieved from Chen et al., 2014).

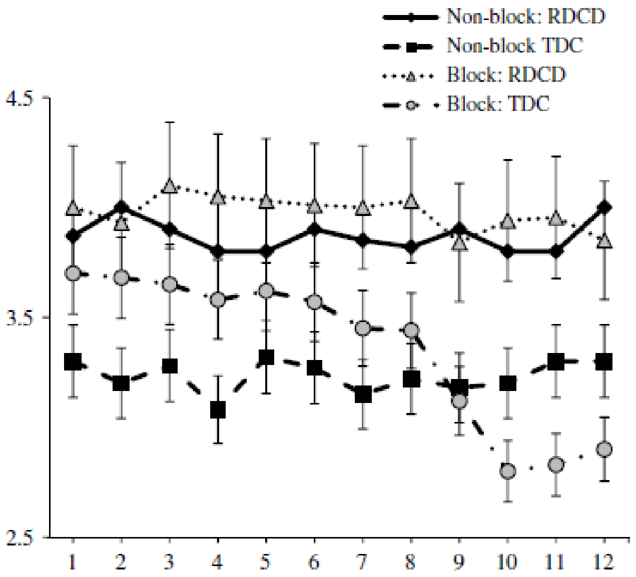

Figure 7 – Mean postural sway in AP axis for the head and torso during the trials (adapted from Chen et al., 2014).

In conclusion, the Chen, Tsai and Wu´s (2014) study revealed that RDCD children compared to the typical ones, were less able to adjust their postural sway, less accurate in interpreting the perceptual judgments, and didn't reveal a learning effect along trials.

Donker and their collaborators (Donker et al., 2008) also studied postural control in children with motor disabilities. The investigators studied and compared 9 CP and 9 typical children between 5-11 years in several conditions: simply standing quietly with eyes open, eyes closed, and with a visual focus or visual feedback. The purpose of the study was to analyse the amount and regularity of the COP (by calculating sample entropy, less entropy higher regularity). The study revealed that CP children oscillations tended to be larger and more regular (with less sample entropy) than that of typical children, in addition, visual feedback promoted a less regular sway in all children yet less pronounced in CP (Figure 8). Consequently, the investigators concluded that CP children could benefit from interventions involving functional tasks.

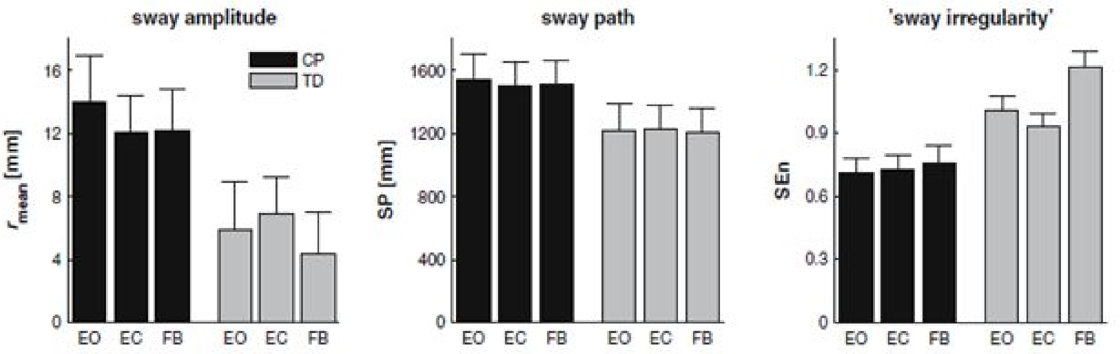

Figure 8 – Postural control variables of CP (in black) and typical children (in grey) in eyes open (EO), eyes closed (EC) and with visual feedback (FB) (adapted from Donker et al., 2008)

Recently, nonlinear methods have also been used to evaluate postural control in children including children with motor disorders. It has already been proven that LyE can detect motor delay in infants. Deffeyes, Harbourne, DeJong, et al. (2009) analysed one of the first motor milestones: the sitting posture. The study was composed of 33 typical infants (5±0.6 months of age) and 26 presenting delayed development diagnosed with or at risk of cerebral palsy (CP) (13.3±3.4 months of age). Data collection occurred when the infants had just developed sitting position to the point where they could remain independently seated for about 10 seconds. The Gross Motor Quotient of Peabody Developmental Motor Scale-2 was used to evaluate motor development; children with visual or musculoskeletal problems were not included. The data were collected with the aid of a force platform, the initial sitting stage was detected by the following criteria: a) the head must be controlled and supported by the trunk without bobbing for over 1 minute, b) the infant could track an object or toy without losing head control, c) the infant could prop hands on floor or legs to lean on arms, but should not be able to reach and maintain balance in the prop sit position, d) when supported in sitting, could reach for a toy, e) the infant could prop on elbows in the prone position for at least 30 seconds. Time series of 2000 data were collected at 240 Hz. The trials lasted 10 seconds, and the collection ended when three acceptable trials were attained, or the children revealed fatigue. For data analyses, no filter was applied, to avoid changes in nonlinear measurements. Significant differences between typical and delayed developing infants for the LyE were found, for both anterior-posterior and mediolateral directions, with delayed developing infants revealing a lower LyE.

The authors proved that infants with developmental delay would be more periodic in postural sway than typical ones. The ApEn was not sensitive to differences between groups. This study proved that LyE can be used to discriminate differences in postural sway between typical and delayed development groups of infants.

Kybelidou and collaborators (2013) studied sitting postural control in infants with a typical development, motor delay and CP, with linear measurements and LyE to determine if they differed in postural control. The sample was composed of 30 infants, born at term with a normal development (5.04±0.55 months of age), 5 infants born preterm who were delayed in motor development (11.56±1.18 age months), and 6 infants born preterm diagnosed with CP (18.1±4.49 age months). The Peabody Gross Motor Scale II was used to evaluate motor development in infants. Each infant participated in 2 sessions, over a week. During the sessions the infant was undressed and placed in the middle of a force platform that was covered with a pad. Trials were performed until three were acceptable by the following criteria: a) the infant did not move his/her arms, b) the infant did not vocalize or cry, c) the infant has not fallen, d) the infant's thorax was not inclined more than 45º either side, e) the infant was not touched, f) the arms position of the infant was noted during the entire trial. The centre of pressure was recorded for anterior-posterior (AP) and mediolateral (ML) directions. It was only considered a trial after at least 8.3 seconds, value was obtained by the sampling frequency according to power spectra analysis. The results showed significant differences among groups in linear measurements (Figure 9). The AP range of CP was significantly lower than for infants with development delay (DD), while ML range didn't reveal significant differences. The nonlinear measurements also showed significant differences in AP and ML directions between groups (Figure 10). Typical infants (TD) had a significantly higher LyE in AP than CP infants. In MD directions CP revealed a significantly lower value than TD and DD. The lower LyE and range in CP indicates that these children had less options or a tendency to diverge less than the others. Implications in therapy are assumed, normally, the variability is not the focus of the therapists but the stability of the movement. However, we can now know affirm that CP children have fewer modes for maintaining sitting balance, what they do have is stability, not variability. . Therefore, variability can be a working point, by constraining CP children to multiple ways of adjustment to sitting positions during daily tasks.

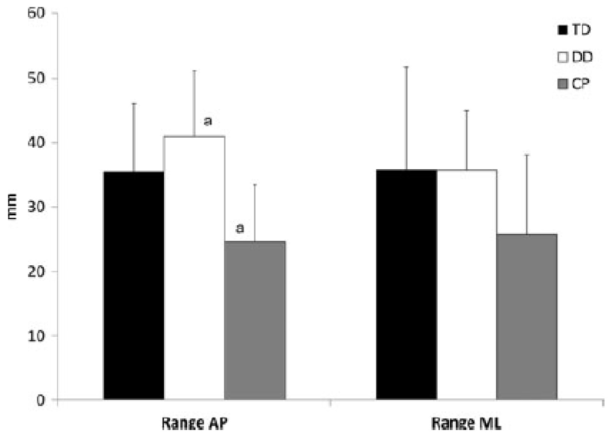

Figure 9 – Range in AP and MP directions for TD, DD and CP groups. The superscript indicates significant differences between DD and CP groups (retrieved from Kyvelidou et al., 2013).

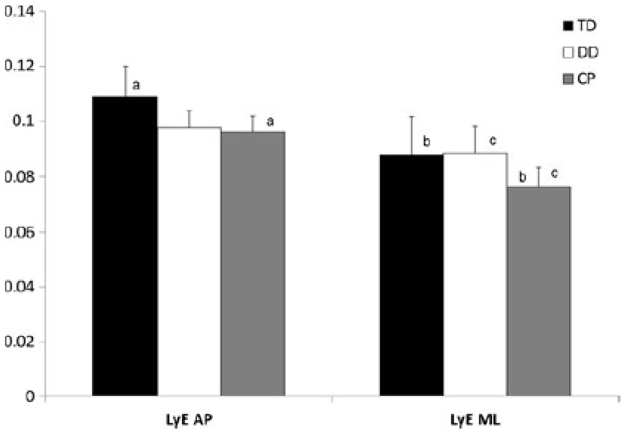

Figure 10 – LyE in AP and ML directions. The superscript b indicates significant differences between TD and CP groups, and c between DD and CP (retrieved from Kyvelidou et al., 2013).

Still in CP, Mercê et al. (2016) studied CP children postural control during sitting position in the following tasks: i) be simply seated(baseline); ii) observing the modelling of a plasticine ball; iii) moulding a plasticine ball; and, iv) idem iii) with closed eyes. The sample was composed of 5 children, of both genders, with 12 ± 1 years of age, and CP levels I and II (Eliasson et al., 2006). Data were collected at 240 Hz, in vertex and C7 points, and analysed through Kinovea and recurrence analysis (Weber & Zbilut, 2005). Compared to the condition i), in condition ii) children were more deterministic, periodic and complex but less stable. Probably, the focus on movements implied a reorganization of postural control. In conditions iii) and iv) children were less deterministic, periodic, stable and complex at the C7, but more periodic, stable and complex at vertex; probably, due to the need to stabilize the head. When performing a functional motor task (conditions iii and iv), children changed their pattern of postural control, with likely increase in degrees of freedom, anchored in the stabilization of the head. The introduction of a visual focus (condition ii)), caused a postural adjustment, probably resulting from the activity of mirror neurons. When performing a functional task (conditions iii) and iv)), the postural adjustment was anchored in fixing the head and trunk release.

3. Synthesis and Problem Presentation

The developmental coordination disorder affects 5-6% of school-age children (Vaivre-Douret, 2014; Vaivre-Douret et al., 2011), who reveal problems in the development of fine or global motor coordination, difficulty in motor control and learning, and in the acquisition of new motor skills (Vaivre-Douret, 2014). One of the most prevalent problems with these children is the postural control deficit, which affects 73 to 87% of them (Macnab et al., 2001).

An early diagnosis accompanied by an early intervention may help to remediate the negative effects of DCD and provide a better quality of life (Smits-Engelsman et al., 2013).

To provide the best possible intervention and therapy, first it is necessary to profoundly understand the disorder and how it triggers the problem that we want to lessen. One of the most prevalent and consequently conditioning problems in DCD is postural control deficit which, in turn, affects all of the child's daily activities. Due to its importance, the PC will be the theme of the present research.

To better understand how balance in p-DCD children evolves and differs from typical it is necessary to disturb the system and force it to reorganize itself to analyse and understand how it reacts. In order to analyse PC, incorporating this study in the children's daily routine, it would be interesting to introduce a functional task that they could easily adopt in their daily life(Donker et al., 2008; Mercê et al., 2016).

Bearing in mind that a possible cause for DCD resides in a sensory integration predicament (Vaivre-Douret et al., 2011)to study PC using solely quantitative methods that simply analyse the result and not the process, in which the real issue may reside, could be diminishing. Having said this, and given that the progress in research and science is often related to methodological approaches (Massion, 1994), PC's study should combine methods that can measure the process and how balance evolves over time. Recently, nonlinear methods have proven to be a very useful tool providing information that other methods do not, namely, the quality of movement and how movement is controlled by the system over the course of time (Costa, Batistão, & Rocha, 2013). Intergrading this new methodology, for example, REC and LyE, which has already been successfully used in other motor disorders in CP for instance, would be even more pertinent on account ofthe absence of its use in PC's studies in DCD children (according to our systematic review).

In summary, the present study aims to analyse and describe sitting postural control during a functional task performed on children considered at risk for DCD and on TD children.

Considering a functional task as a task where the movements have a concrete function, applicable to daily activities (Mercê et al., 2016).

The sitting position was selected to allow the replication of the study with cerebral palsy, which largely constraints the maintenance of the standing position, while performing a task (e.g. Mercê et al., 2016).

Various study tasks were defined based on leads by other authors, which provoked an alteration in balance ability in individuals with DCD and other motor disorders. Namely, the introduction of a visual stimulus (e.g. Donker, Ledebt, Roerdink, Savelsbergh, & Beek, 2008), the use of a functional task (e.g. Cravo, 2012; Mercê et al., 2016), and removal of visual stimulus by closing eyes (e.g. Donker et al., 2008; Geuze, 2003).

3.1. Goals

The main purpose of this dissertation was to better understand PC in p-DCD children and take a more in-depth look at clues for a more suitable form of intervention. In an attempt to achieve this aim and to develop the methodology to undertake the study, two other goals were defined.

The first being a systematic review of all the linear and nonlinear methods previously used with DCD children which will be presented in chapter II.

The second goal, is to identify p-DCD in at-risk and typical children by applying a MABC-2 battery test in a population of infants between 3 and 4 years. Its results are explained in chapter III.

The data collected from the systematic review and MABC-2 battery was analysed allowing a grounded definition of the methodology to complete the study on PC in p-DCD children.

Therefore, the present research intended to analyse and compare PC in probable DCD children at risk of developing DCD, and TD children in sitting posture during a functional task. The study's conditions were defined as: i) just being seated; ii) same as i) with the eyes closed; iii) observing the moulding of a plasticine ball; iv) making a plasticine ball; v) same as iv) with the eyes closed. According to the state of the art measuring methods and the systematic review, the application of both linear and nonlinear methods was defined (Deffeyes, Harbourne, DeJong, et al., 2009), for two anatomical points, vertex and cervical 7, in order to understand if PC differs between spine zones (Chen et al., 2014; Mercê et al., 2016).

3.2. Hypothesis

H1: Children at risk reveal a similar behaviour to typical children.

At-risk children are in a transition zone, revealing a few motor development fragilities. However, these fragilities are not yet so limiting that the individuals in question might be classified as DCD. For being in the transition zone, at-risk children may possibly display a similar behaviour to TD. They may even demonstrate different quantitative outputs following the same movement patterns. There is insufficient research into this theme "grey zone", to draw any firm conclusions on this hypothesis. Current literature tends to approach the extremes concerning subjects with and without the disorder, consequently, the aim of our study was to further broaden current knowledge of this behaviour. Lacking support for our findings, we therefore, rely on the results to provide confirmatory evidence of our conclusions.

H2: Probable DCD children are most regular, periodic and complex compared to typical and at-risk children during the sitting condition i) and ii).

Despite the present research not having found an investigation approaching the regularity, periodicity and complexity of the PC in DCD children, according to PC studies in other motor disorders like CP, these children revealed fewer modes of maintaining sitting balance, oscillating more and being more regular, with less sample entropy (Donker et al., 2008); more periodic, lower LyE (Deffeyes, Harbourne, DeJong, et al., 2009; Kyvelidou et al., 2013); and more complex, higher entropy (Mercê et al., 2016). Thus, we suppose that p-DCD could behave similarly to what other studies revealed in CP children.

H3: By introducing an external visual focus, condition iii), children with probable DCD reveal a less regular postural control structure, compared to the condition without visual focus.

According to previous studies, in CP the introduction of a visual focus leads the system to be less regular (Donker et al., 2008; Mercê et al., 2016). Donker and their collaborators (2008) verified that CP children oscillations tended to be larger and more regular than typical, and that visual focus promoted a less regular sway in all children including in CP.Additionally, Mercê and their collaborators (2016) verified that in CP by introducing a visual focus, CP children became more deterministic, periodic and complex but also less stable. The focus on movement implies a reorganization of postural control, we suppose that in p-DCD children this reorganization occurs in the same way.

H4: By introducing a functional task, iv), the children with probable DCD reveal a more regular and complex postural control structure, compared to the condition without the task or external visual focus (Mercê et al., 2016);

Taking into account that the systematic review conducted on the PC studies in DCD children did not explore a functional task in the sense of being a task that the children could replicate in their daily living. The studies are based mainly on standing, walking or doing a cognitive or mental task. However, some authors mentioned the importance of the functional tasks in the intervention with children displaying motor disorders (Cravo, 2012; Mercê et al., 2016). Considering that in CP the introduction of a functional task changed the children's pattern of postural control, demonstrating an increase in degrees of freedom, anchored on head stabilization with a more stable and complex vertex. We believe that p-DCD children also become more regular and complex in this condition.

H5: By introducing a functional task with closed eyes, children with probable DCD reveal a less regular postural control structure compared to the task with eyes open (e.g. Donker et al., 2008).

Previous studies have shown that p-DCD children could be more dependent of visual information (Deconinck, De Clercq, Cambier, Savelsbergh, & Lenoir, 2006; Fong, Tsang, & Ng, 2012; Geuze, 2003; Chia-Liang Tsai, Wu, & Huang, 2008). When this information was removed during static balance DCD children significantly increased their oscillations revealing difficulties in maintaining their PC (Fong et al., 2012; Geuze, 2003; Chia-Liang Tsai et al., 2008); moreover, during the dynamic balance, by walking, DCD children decreased their step frequency and lengthnotably(Deconinck et al., 2006). Hence, recognizing that the loss of visual information affects PC in DCD children, we suppose that for the same functional task this absence of information once again affects their balance making it less regular due to the increased difficulty.

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Chapter II

Systematic Review: Postural Control in DCD and Typical Children

Abstract

Developmental coordination disorder (DCD) is a motor disorder without neural compromising that affects 6% of school-age children. DCD children are a heterogeneous group revealing problems in motor control and learning (Vaivre-Douret et al., 2011a). One of the most prevalent problems is postural control (PC) deficit, which affects 73% to 87% of this population(Geuze, 2003). Several methodologies have been used in PC's study, linear methods providing significantly accurate degree and quantification of several postural variables. Recently, nonlinear methods were introduced giving information about the quality of movement and how movement is controlled by the system over time (Deffeyes, Harbourne, DeJong, et al., 2009).

A systematic review was conducted between 24 February 2016 and 3 March 2016 so as to identify the methodologies formerly used in the PC study on DCD children, and the differences determined between them and typical children with the purpose of identifying clues for a suitable intervention. Article references were searched further for additional relevant publications using the electronic databases: Pubmed, Science Direct, Scopus, Web of Science, Cochrane and Scielo. The search was performed in English, French, Portuguese and Spanish. 9 articles were retrieved for analysis, being that no articles mentioning nonlinear methods were found.

Although remaining unclear to this day, previous studies suggest that DCD children are more dependent on visual information (VI) (Deconinck et al., 2006; Fong et al., 2012; Tsai et al., 2008). In standing condition DCD children revealed to be more variable and oscillate more than typical, especially with increasing difficulty, e.g. without VI (Przysucha & Taylor, 2004; Tsai et al., 2008) or doing tasks simultaneously (Chen, Tsai, Stoffregen, & Wade, 2011; Chen, Tsai, Stoffregen, Chang, & Wade, 2012; Tsai, Pan, Cherng, & Wu, 2009). In walking balance with no VI, DCD children significantly decreased their step frequency and step length, walking slower (Deconinck et al., 2006).

Taking into account all studies analysed, for a more suitable intervention with DCD children we should: consider attentional factors (Chen et al., 2012; Tsai et al., 2009); work on the perception-action link (Chen et al., 2011; Fong et al., 2012); work on the timing of gastrocnemius contraction and improve this peak force (Fong et al., 2015); moreover, increase the limit of stability in backward excursion (Fong, Guo, et al., 2016).

Keywords: Postural control, children, DCD, linear, nonlinear

1. Introduction

The developmental coordination disorder (DCD) is a motor disorder identified and recognized by the Diagnostic and Statistical Manual of Mental Disorders (DSM-MD) (American Psychiatric Association, 2013). This disorder is expressed early, affecting 6% of school-age children (Vaivre-Douret, 2014; Vaivre-Douret et al., 2011). The children with DCD reveal problems in the development of fine or global motor coordination, difficulties in the motor control and learning, and in the acquisition of new motor skills (Vaivre-Douret, 2014). These difficulties are expressed in many ways, like in a delay of achieving motor milestones, clumsiness, poor balance, difficulties in writing and drawing (Chang & Yu, 2010), poor postural control (Geuze, 2005), and difficulties in space and temporal organization (Wilson & McKenzie, 1998b); affecting the daily life of the children which, consequently, brings more problems and new difficulties like academic delay or social isolation (Joshi et al., 2015; Vaivre-Douret, 2014). For example, a child who cannot maintain his posture in the chair and simultaneously has difficulties in drawing letters correctly, will be a child that is neither focussed on the lesson nor the teacher but rather on drawing a letter, resulting in academic impairments.

The difficulties remain for life, DCD does not simply disappear as time goes by (Cousins & Smyth, 2003b). An early diagnosis accompanied by an early intervention may help to decrease the negative effects of DCD, and provide a better quality of life for these children, and later, in their adult life (Bouwien C. M. Smits-Engelsman et al., 2013b).

Children with DCD are a heterogeneous group, they can reveal just some part of the symptoms and not all simultaneously, e.g., the child can reveal balance problems but no visual and spatial difficulties and vice versa (Vaivre-Douret et al., 2011). One of the most prevalent problems is the postural control deficit, which affects 73% to 87% of the DCD children (Macnab, Miller, & Polatajko, 2001b). The postural control is crucial for all daily tasks like walking, running, playing, putting the groceries on the shelf, picking up an object from the ground, reacting to an unexpected disturbance (like avoiding an obstacle). Due to the significance of postural control effect on daily routines it is very pertinent to study the postural balance in DCD children. If we understand how balance control is performed, and the differences between typical and DCD children in this capacity, we will be able to make a more adjusted intervention with better results.

In recent years, new ways of looking at and interpreting postural control data have been increasing. Previously, only the linear and quantification methods like the COP analysis in sway, path range or coefficient of variation were used. Nowadays the nonlinear methods are emerging and represent a very useful tool, which can provide information on the quality of movement and how the movement is controlled by the system over time (Costa, Batistão, & Rocha, 2013). Recently, nonlinear methods have successfully demonstrated sensitivity to small alterations in postural control and to be able to discriminate pathologic from non-pathologic disorders, e.g. detection of infants with cerebral palsy (da Costa et al., 2013a; Deffeyes, Harbourne, Stuberg, & Stergiou, 2011; Kyvelidou et al., 2013; Surkar, Edelbrock, Stergiou, Berger, & Harbourne, 2015).

Considering the importance of PC's study in DCD children, which affects their daily living, and bearing in mind the value that linear methods had already proved in the past and also the potential of the recent application of nonlinear methods. It would be of significant importance to review all the methodologies already used in PC's study in DCD to give a holistic view to investigators of what has already been done in this field and, subsequently, what can be improved in future studies. Only an appropriate and careful use of the methodology will allow us to achieve solid and reliable results. Beyond the methodology, it would be interesting to analyse and synthetize the results found for PC in DCD children and the differences between them and typical, in order to more deeply understand this theme and, If possible, find clues for a more suitable intervention.

Overall, the purpose of this systematic review consists of identifying all the methodologies, linear and nonlinear, that have been used in the PC study in DCD; and also analyse and synthetize the differences that they found between these and typical children. The raised questions were: i) which methods were used to evaluate postural control in children with DCD?; ii) which differences were found between the postural control in DCD children and children with typical motor development?

2. Methods

2.1. Search Strategy

A literature search according to PRISMA guidelines (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2009) was conducted using the electronic databases Pubmed, Science Direct, Scopus, Web of Science, Cochrane and Scielo. These databases were selected as they represent a wide spectrum of disciplines that perform research in DCD (e. g. Adams, Lust, Wilson, & Steenbergen, 2014). The search was performed between 24 February 2016 and 3 March 2016, all articles presented in the databases in this time frame were scrutinized. Due to the wide range of different terminology to refer postural control, a combined search using the equivalent terms has been chosen; an equivalent term, the acronym and the complete designation for DCD were used. To maximize the spectrum of the search, this was performed in English, French, Portuguese and Spanish using the following key terms in the advanced search: English – ((developmental coordination disorder) or (dyspraxia) or (DCD)) and (postural balance) or (postural sway) or (postural control); French – (("développement des troubles de coordination") or (dyspraxie) or (DCD)) and ((contrôle postural) or (l'équilibre postural) or (balancement postural)); Portuguese - (("desordem coordenativa do movimento") or (desordem coordenativa no desenvolvimento) or (DCD) or (dispraxia)) and ((controle postural) or (controlo postural) or (oscilação postural) or (equílibrio postural)); Spanish - (("Transtorno de la coordinación del desarrollo") or (dispraxia) or (DCD)) and ((control postural) or (equilibrio postural) or (oscilación postural)).

2.2. Inclusion and exclusion criteria

The inclusion and exclusion criteria for this systematic review were similar to another review on the topic of DCD (Adams et al., 2014), consequently, were discussed and defined by all authors.

As inclusion criteria the authors only considered studies that: i) had been published in peer reviewed journals; ii) had had a DCD group evaluated by a standardized assessment of motor skills to diagnose a probable DCD, such as, Movement Assessment Battery for Children 1 or 2 (Henderson & Sugden, 1992; Henderson, Sugden, & Barnett, 2007) and/or Bruininks Test of Motor Proficiency-2 (Bruininks & Bruininks, 2005); iii) had a control group with typical development; iv) had used, at least, one nonlinear measurement/method to analyze postural control; v) incorporated children until 10 years old, this age limit was defined based on the final stage of third infancy, where children developed expertise and a combination of motor skills. The exclusion criteria were the following: i) not reviewed by pairs; ii) books or chapters; iii) studies of qualitative nature; iv) studies in which the DCD group has violated the DSM-IV-TR criteria for this disorder, such as children with an identifiable neurological disorder, an IQ score outside the normal range or children with any (gross) physical or sensory impairment.

2.3. Identification of eligible articles

After completing the search in the different languages, 1 302 records were identified (English- 834, French- 116, Portuguese- 27, Spanish- 325), which were reduced to 598 after removing duplicates.

Subsequently, the title reading was carried out, where 67 potentially relevant articles were identified. This marked decrease of potential articles, from 598 to 67, was the result of a combined search with the terms “postural control” that retrieved articles including other disorder like CP, autism or Asperger in which we had no interest.

Based on the abstract reading 34 articles were excluded: 8 for not being an article reviewed by pairs, 2 for being a systematic review, 2 for not including a DCD group, 8 due to the absence of postural control’s analyses, and 14 for not corresponding to the age group selected.

After a full reading a further 24 articles were excluded: 3 for not using a standard instrument to access DCD, 14 for violating DSM-IV-TR, and 7 for not corresponding to the age group selected.

In the end just 9 articles were considered for the present systematic review, all of which included linear methods with no reference whatsoever to nonlinear methods, details can be found in Figure 11.

After screening each eligible paper, the following data were extracted: sample size, mean and standard deviation of sample’ age, tasks, tools, outcome variables, results and conclusions.

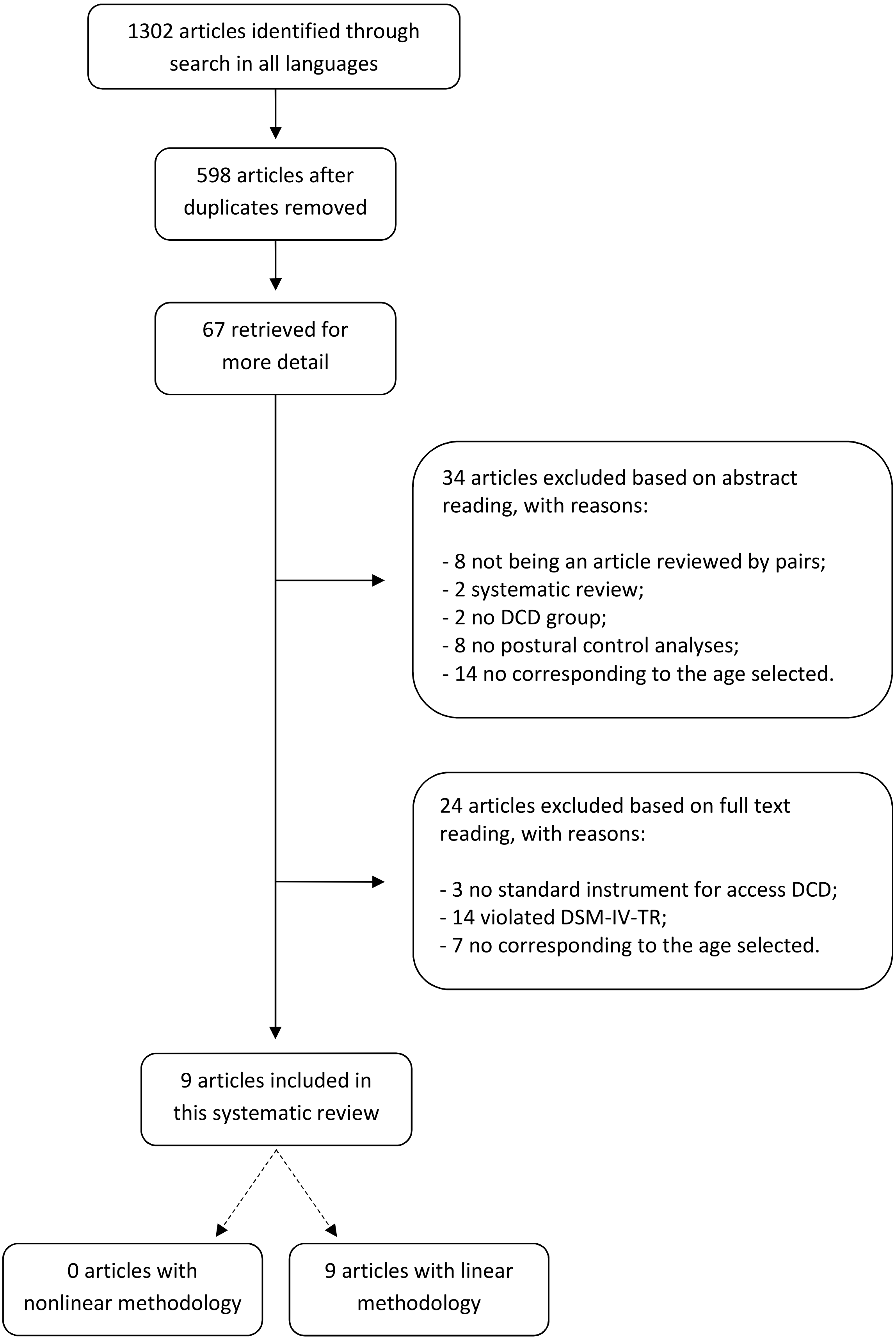

Figure 11 – Flow chart of the articles searched

3. Results

The data retrieved from the eligible studies are presented in Table 2 below. All studies incorporated a DCD and a control group, the sample sizes across the DCD group ranged from 12 to 130, and in control group from 12 to 117. All studies reported the mean age and standard deviation. With regard to the tools and outcome variables, all studies used biomechanical instruments including force platforms (Przysucha & Taylor, 2004); three-dimensional video record (Deconinck et al., 2006); a balance performance monitor (Tsai et al., 2008; Tsai et al., 2009); a magnetic tracking system (Chen et al., 2011; Chen et al., 2012); a computerized dynamic system (Fong, Guo, et al., 2016; Fong et al., 2012); electromyography, accelerometer and dynamometer (Fong et al., 2015). All studies performed kinematic analysis and only one also included kinetic analysis (Fong et al., 2015). In almost all studies the tasks changed to standing position, except in one which analysed walking (Deconinck et al., 2006). In 3 studies an additional task was performed besides standing (Chen et al., 2011; Chen et al., 2012; Tsai et al., 2009). No study was found using nonlinear methodology.

Table 2 - Studies' synthesis table

Study	Participants	Age	Tasks	Tools	Outcome Variables	Results	Conclusions
(Przysucha & Taylor, 2004)	20 DCD boys 20 TD boys	8.6 ± 2.1 8.5± 2	1st Standing quiet with eyes open 2nd Idem in eyes closed	1 AMTI force platform	Kinematic COP analysis in: - Anterior-posterior (AP) sway - Lateral (Lat) sway - Path length (L) - Area of sway (Ao) Romberg's quotient	- No significant difference between groups in LAT or L - Boys with DCD demonstrated a higher AP sway ($p < .01$) and Ao ($p < .03$) - Romberg's quotient indicated that boys with DCD did not over-rely on visual information	Boys with DCD are able to compensate as effectively as TD for the loss of visual input while maintaining quiet stance

(Deconinck et al., 2006)	12 DCD 12 TD	7.8 ± 0.52 7.7 ± 0.56	- Walk at their preferred speed with lighting - Same in dark The order conditions were randomized	8 Three-dimensional ProReflex cameras recording at 240 Hz	Kinematic Spatiotemporal gait variables: - Stride length - Stride frequency - Stride velocity - Support time - Swing time - Double support time	- With light the gait pattern was similar between groups - In dark, step frequency and step length were decreased in the DCD children, with significantly slower walking (p<0.001) -Velocity and the medio-lateral excursion of COP tended to increase in DCD	The study suggest that DCD are more dependent on visual information than TD for the maintenance of balance and the control of velocity during walking
(Tsai et al., 2008)	64 DCD-BP 71 TD	10.1 ± 0.3 10.3 ± 0.2	With and without vision standing still 30'' on: -dominant leg -non-dominant leg -both legs First eyes open and then closed during both the two-leg and one-leg stances	Balance performance monitor (BPM) composed by a feedback unit and a set of force platforms, recording at 100 Hz	Kinematic COP analysis in: - Sway area - Total path length Romberg's quotient	- In all conditions DCD-BP children demonstrated greater total path length and sway area than TD - DCD-BP showed significantly larger maximum COP excursions, especially with closed eyes - Romberg's coefficient indicated that DCD-BP did not over-rely on visual information	Static balance abilities of children with DCD-BP were significantly worse, especially when standing with eyes closed, than for TD (significant lower sway area and total path)
(Tsai, Pan, Cherng, & Wu, 2009)	39 DCD-BP 39 TD	9.7 ± 0.4 9.6 ± 0.2	- For 30'' just standing; - Idem doing five dual-tasks: oral counting task (OC), auditory–verbal reaction task (AV), auditory–choice reaction task (AC), auditory–memory task (AM) and articulation (AA) - Standing with eyes-closed	Balance Performance Monitor, 100 Hz	Kinematic Sway area of COP Variation index Romberg coefficient	- No significant differences in single task or dual-task balancing between groups - For intra-group comparisons no significant differences in TD for dual task in relation to baseline - DCD-BP increase significantly their sway path in OC, AV and AM (p=00.3, p=0.011, p=0.041 respectively) - Romberg coefficient suggested that DCD-BP did not over-rely on visual information	The study suggests that children with DCD-BP were more cognitively dependant and may have an automatization deficit

(Chen, Tsai, Stoffregen, & Wade, 2011)	32 DCD 32 TD	9.4 ± 0.5 9.21 ± 0.42	While standing do a visual task of signal detection in a monitor: - Low difficulty (LD) -High difficulty (HD) The order conditions were randomized	Magnetic tracking system, 60 Hz	Kinematic Positional variability (standard deviation of position) for: - Head and torso - Anteroposterior and mediolateral direction	- DCD group exhibited a significant higher positional variability than the TD group for head and torso motion in all conditions (p<0.05) - Both groups modulated their postural activity in response to difficulty variations - The effect of visual task (HD vs. LD) on postural activity differed for TD and DCD groups. TD reduced postural motion in the HD while DCD increased	The study suggests a weakened perception-action link in children with DCD as they seem less able to reduce postural control to benefit signal detection performance
(Chen, Tsai, Stoffregen, Chang, & Wade, 2012)	38 DCD 38 TD	9.37 ± 0.49 9.21 ± 0.41	While standing do a digital memory task at two levels: - Low difficulty (LD) -High difficulty (HD) The order conditions were randomized	Magnetic tracking system	Kinematic Positional variability (standard deviation of position) for: - Head and torso - Anteroposterior and mediolateral direction	- DCD exhibited significantly larger postural motion (p<0.05) than TD - TD modulated their sway in response to variations in task difficulty, they significantly reduced postural motion in the HD (p<0.05) compared LD, DCD did not	The study suggests that the postural responses of DCD differ from TD while engaging in a memory task with various difficulty levels Also suggest that DCD had a reduced ability to modulate postural motion when engaged in cognitive activity
(Fong et al., 2012)	22 DCD 19 TD	7.5 ± 1.4 6.9 ± 1.1	6 Conditions: - 1st Eyes open, fixed support - 2nd Eyes closed, fixed support - 3rd Sway-referenced vision, fixed support - 4th Eyes open, sway-referenced support - 5th Eyes closed, sway-referenced support - 6th Sway-referenced vision and sway-referenced support	Computerized dynamic posturography machine to perform a sensory organization test (SOT)	Kinematic Equilibrium score (ES) for AP direction Composite ES (considering ES in all the six conditions) Somatosensory, visual and vestibular ratio	- DCD had lower composite ES (p < .001), visual ratios (p = .005) and vestibular ratios (p = .002) than TD - DCD had lower motor strategy scores (swayed more on their hips) than the normal children when forced to depend on vestibular cues alone to balance (p < .05)	DCD had deficits in standing balance control in conditions that included reduced or conflicting sensory signals The visual and vestibular systems tended to be more involved in balance deficits than somatosensory DCD children tended to use hip strategy excessively when forced to rely primarily on vestibular signals to maintain postural stability

(Fong et al., 2015)	130 DCD 117 TD	7.7 ± 1.4 7.4 ± 1.3	Standing with: - eyes closed - Idem with an unexpected perturbation - Voluntarily contracting their leg muscles as hard and as fast as possible For balance and motor skill performance it was used MABC scores	Electromyography Accelerometer Dynamometer Lafayette Manual Muscle Test System	Kinematic and kinetic Hamstring and gastrocnemius: - Muscle activation latencies - Muscle peak force - Time to peak force	- DCD had longer hamstring and gastrocnemius muscle activation latencies (P<0.001) and lower isometric peak forces (P<0.001) - Gastrocnemius peak force explained 5.7% (P=0.003) and 8.5% (P=0.001) of the variance of MABC balance subscore and ball skills subscore respectively - Gastrocnemius muscle activation latency explained 11.4% (P<0.001) of the variance in the MABC ball skills subscore	- DCD had delayed leg muscle activation and lower isometric peak forces - Gastrocnemius peak force was associated with balance and ball skills performances, whereas timing of gastrocnemius muscle activation was a determinant of ball skill performance in the DCD population - Improving the timing of gastrocnemius muscle activation and strengthening should be included in the rehabilitation treatments to improve postural control
(Fong, Ng, et al., 2016)	30 DCD 20 TD	7.7 ± 1.5 7.9 ± 1.6	Standing at force platform without moving their feet and watching their COP projection in a visor, children should redirect their COP by redistribute their weight in the feet to reach target positions that were randomly selected	Computerized dynamic posturography to perform limit of stability test (LOS)	Kinematic LOS in standing reaction time Movement velocity Maximum excursion End point excursion Directional control Self-reported fall incidents in the previous week	- DCD had shorter LOS maximum excursion in the backward direction compared to the control group (p = 0.003) - This was associated with a higher number of falls in daily life (p = 0.001) - DCD had direction-specific postural control impairment, specifically, diminished LOS in the backward direction.	- Improving LOS should be factored into rehabilitation treatment for children with DCD

Abbreviations: DCD – developmental coordination disorder; TD – typical development; DCD-BP- DCD with balance problems; COP – centre of pressure; AP – anterior-posterior sway; Lat – medio-lateral sway; L – path length; Ao – area of sway; BPM – balance performance monitor; OC – counting task; AV – auditory–verbal reaction task; AC – auditory–choice reaction task; AM – auditory–memory task; AA – articulation; LD – low difficulty; HD – high difficulty; SOT - sensory organization test; CDP – Computerized dynamic posturography; ES – equilibrium score; LOS - Limit of stability

Visual Information

The importance of visual information to PC in DCD was approached in 5 out of the 9 studies, which incorporated tasks with and without visual information (Deconinck et al., 2006; Fong et al., 2012; Przysucha & Taylor, 2004; Tsai et al., 2008; Tsai et al., 2009).

In 3 studies the Romberg's coefficient was performed (RC), this may provide a simple clinical description of the degree of dependence on visual input in balance maintenance, calculated by ((eyes closed/eyes open) x 100%) when RC is larger than 100%, this indicates more sway with eyes closed than open. In all of the 3 studies, and although they found RC's values to be higher than 100%, it was considered that the coefficient didn´t indicate that DCD children over-rely on visual information due to the absence of significant differences (Przysucha & Taylor, 2004; Tsai et al., 2008; Tsai et al., 2009). Przysuvha and Taylor (2004) even concluded that DCD boys are able to compensate the loss of visual information in quiet standing balance as effectively as typical boys. However these findings differ from other authors, Deconinck and their colleges (2006) suggested that DCD children are more dependent on visual information than typical for maintaining balance in walking; Tsai, Pan, Cherng and Wu (2009) found that DCD did not perform as well as typical in maintaining balance, especially with the absence of visual information; also Fong, Tsang and Ng (2002) reported that visual systems tended to be more involved in balance deficits in DCD children.

Kinematic Analysis

Relating to the kinematic variables the DCD children seem to be more variable and to oscillate more than typical. Boys with DCD revealed a significantly higher sway in AP direction ($p<0.01$) and in the total area of sway ($p<0.03$) than typical boys in just standing still, with higher values with no visual information (Przysucha & Taylor, 2004). Again in just standing still on both legs, dominant and non-dominant leg, DCD children had greater total path length and sway area than TD, and also revealed a significantly larger excursion of COP especially with eyes closed (Tsai et al., 2008). While doing a memory task with low and high difficulty DCD children always revealed a significantly higher positional variability in head and torso than TD ($p<0.05$) (Chen et al., 2012). The same had occurred during a visual detection task with low and high difficulty, once again DCD children had a significantly higher positional variability to head and torso under all conditions ($p<0.05$), being that long TD in high difficulty decreased their sway DCD increased (Chen et al., 2011). Analysing posture during cognitive tasks DCD children tended to oscillate more, and this difference was significant during an oral-counting task ($p=0.03$), auditory-verbal reaction ($p=0.011$) and auditory-memory task ($p=0.041$). This increased oscillation is even more notorious in the hips, DCD children tended to use hip strategy excessively, swayed more ($p<0.05$), when forced to rely on vestibular signals (Fong et al., 2012).

When we leave the standing analysis, and look at walking balance, DCD children had a similar pattern to TD with lighting, showing a slightly longer support phase. But in a harder task, walking in the dark, these children decreased their step frequency and step length substantially ($0<0.001$) walking significantly slower (Deconinck et al., 2006).

Kinetic Analysis

Along with a longer hamstring and gastrocnemius activation latencies ($p<0.001$), DCD children also revealed a lower isometric peak forces for these muscles ($p<0.001$) (Fong et al., 2015). This low peak force of gastrocnemius explained 5.7% ($P=0.003$) and 8.5% ($P=0.001$) of the variance of MABC balance score and ball skills score respectively. While Gastrocnemius muscle activation latency explained 11.4% ($P<0.001$) of the variance in the MABC ball skillsscore.

4. Discussion

The purpose of the present research consisted on reviewing all the methodologies already used in PC's study in DCD; and analysing and synthetizing the results and differences between DCD and typical children in these studies, in order to more deeply understand this theme and find clues for a more suitable intervention.

Despite there being few studies, just 9, all of which have used biomechanical instruments, we found diversity in the methodology. Force platforms, three dimensional video recording, balance performance monitor, magnetic tracking system and computerized dynamic posturography were used to access the COP's participants, so as to study their postural control. Besides the COP analysis, we also found limit of stability tests, and equilibrium scores through the sensory organization tests, electromyography, accelerometer and dynamometry. We can accept that it is possible to study postural control with a broad and varied methodology.

Unfortunately, considering the present systematic review, until now, the nonlinear methods were not yet applied in studies of postural control in DCD, so we cannot synthesize and analyze information about those particular studies. The nonlinear methods like approximated entropy or Lyapunov exponent have been used in the study and diagnosis of developmental delay in infants and children with several disorders, like cerebral palsy (Deffeyes et al., 2011), and proved to be able to supply additional information to linear methods.

Considering that the first goal of this research consisted of reviewing the methodology already used in PC's study in DCD, in order to gather information on what investigators can improve in future. Our suggestion consists of supporting linear and nonlinear methods, as already done in CP (Deffeyes et al., 2011), using, if possible, a triangulation method. It is possible that this new nonlinear technology, allied to other linear that has already proved to be reliable and valuable, in future we can find more information to better understand this theme.

The second purpose, was to synthetize and analyse information, looking at the linear data and for all studies including the fact that visual information in balance control of DCD children is still unclear, among the 5 studies that approached this theme 1 did not present a conclusion or suggestion (Tsai et al., 2009), another suggested that boys with DCD can compensate effectively the absence of visual information as typical (Przysucha & Taylor, 2004), and 3 studies suggested a greater dependency on visual information in DCD children (Deconinck et al., 2006; Fong et al., 2012; Tsai et al., 2008). It seems possible that DCD children are more dependent on visual information.

In a general, DCD children appear to be more variable and oscillate more in a standing condition especially when the task becomes more difficult, e.g. loss of visual information (Przysucha & Taylor, 2004; Tsai et al., 2008) or doing tasks simultaneously (Chen et al., 2011; Chen et al., 2012; Tsai et al., 2009).

This increasing oscillation when the task difficulty increases in DCD is not fully proved, when we leave the standing analysis and look at walking balance DCD walking in the dark significantly decreased their step frequency and step length (0<0.001) walking slower (Deconinck et al., 2006). Despite several studies having noted a higher oscillation in DCD, these children had a shorter limit of stability in backward direction (p=0.003) which was related to a higher number of falls (Fong, Guo, et al., 2016).

Analysing the conclusions and suggestions of all studies included in the present research, it was possible to identify some clues for intervention with DCD children. Some studies suggested that DCD were more cognitively dependant and may have an automatization deficit, which means that the intervention should take into account attentional factors (Chen et al., 2012; Tsai et al., 2009). Other studies reported a deficit in standing balance with reduced or conflicting sensory signals, and also suggested a weakness in the perception-action link (Chen et al., 2011; Fong et al., 2012). This should be another field to explore in the intervention, the child is not a system closed on itself, it is rather a dynamic system which, consequently, is influenced by the environment. If the child has problems accessing and incorporating the information available, the cycles of perception-action, he/she will have problems in using it to maintain its posture and/or fulfil a task.

It was also found that the late timing of contraction and the lesser peak force of the gastrocnemius muscle are related to a higher incidence of falls in DCD children (Fong et al., 2015). Besides that, the limit of stability in backward excursion of DCD children is significantly lesser (Fong, Guo, et al., 2016). All of these aspects should be addressed in physical therapy in order to improve balance control in these children.

5. Conclusion

According to the present research, the nonlinear methods have not yet been applied to studies of postural control in DCD. Our suggestion is to ally linear and nonlinear methods, as previously done in CP (Deffeyes et al., 2011), using a triangulation method if possible.

Within the linear methodology used different approaches were found like COP analysis, limit of stability tests, equilibrium scores, electromyography, accelerometer and dynamometry, all using biomechanical instruments. We can accept that it is possible to study postural control with a broader and varied methodology.

The importance of visual information in PC of DCD children is still unclear, however it seems possible that DCD children are more dependent on visual information (Deconinck et al., 2006; Fong et al., 2012; Tsai et al., 2008).

In general, DCD children seem to be more variable and oscillate more in a standing condition especially when the task becomes more difficult, e.g. loss of visual information (Przysucha & Taylor, 2004; Tsai et al., 2008) or performing tasks simultaneously (Chen et al., 2011; Chen et al., 2012; Tsai et al., 2009). However,as mentioned previously, whenwalking balance in the dark was analysed, DCD children decreased their step frequency and step length significantly, walking slower (Deconinck et al., 2006).

According to the studies analysed we can identify some clues for a more suitable intervention with DCD children: take into account attentional factors (Chen et al., 2012; Tsai et al., 2009); work on the perception-action link (Chen et al., 2011; Fong et al., 2012) bearing in mind that the child is a dynamic system which is influenced by the environment, and needs this information to maintain its posture and/orperform a task; work on the late timing of gastrocnemius contraction compared toTD, and also improve its peak force (Fong et al., 2015); increase the limit of stability in backward excursion which is significantly less (Fong, Guo, et al., 2016).

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Chapter III

Prevalence of Developmental Coordination Disorder in Rio Maior and São João da Ribeira in children with 3 and 4 years old

(Article submitted to Medi@ções review, in review process)

Abstract

The developmental coordination disorder (DCD) is a motor disorder without neural compromising that affects 5-6% of children in school-age (Zwicker, Missiuna, Harris, & Boyd, 2012). DCD children reveal problems in their development of fine or global motor coordination, difficulty in the motor control and learning, and in the acquisition of new motor skills (Vaivre-Douret, 2014).

The present study aims to identify and describe the prevalence of probable DCD in Rio Maior and São João da Ribeira in children with 3 and 4 years . A MABC-2 battery test was applied(Henderson & Sugden, 2007) in 46 children (3.9±0.26 years old, 25 girls and 21 boys) from 3 preschools.

2 children were identified has having probable DCD, corresponding to 4.4% of the sample, 7 children as being in the risk zone, 15.2% of the sample; and 37 children revealed values of a typical motor development, 80.4% of the sample. A prevalence of left-handedness was verified in probable DCD children (Cairney et al., 2008; Flouris, Faught, Hay, & Cairney, 2005). The least scored categories were aiming-catching for typical development and probable DCD children, and balance for at risk children; probably due to the involvement in fewer activities requiring aiming-catching and balance tasks, contrasting with a bigger incidence in manual dexterity activities, in order to prepare children for primary school.

This study also clarifies the importance of the MABC-2 application in order to identify not only the probable DCD children, but also at-risk children, which had a greater incidence of 3.4 times than the first group.

Key-words: DCD, children, MABC-2, laterality

1. Introduction

The developmental coordination disorder (DCD) is a motor disorder without neural compromising identified and recognized by the Diagnostic and Statistical Manual of Mental Disorders (DSM) (American Psychiatric Association, 2013), which affects 5-6% of children in school-age (Zwicker et al., 2012). This disorder normally affects more boys than girls, with proportions from 2:1 to 5:1 (CanChild, 2016); however it’s possible to find studies where this relation is not established (Cairney et al., 2008).

Generally referred to as “clumsy”, the children with DCD experience motor coordination difficulties that dramatically affects their daily life, and can also affect their academic achievements (CanChild, 2016). These children usually reveal a delay in attaining motor milestones such as crawling or walking; problems in their fine and/or gross motor skills, e.g., tasks as drawing or jumping with both feet can be extremely difficult; they possess a slower and less accurate motor performance (Zwicker et al., 2012); have poor balance control (Geuze, 2005); reveal difficulty in the acquisition of new motor skills, like tying their shoelaces or riding a bike (Vaivre-Douret, 2014); and difficulties in spacial and temporal organization (Wilson & McKenzie, 1998). DCD children are a heterogeneous group, as they can reveal just part of the symptoms and not all simultaneously, e.g., the child can reveal balance problems but no spatial difficulties, or vice versa (Vaivre-Douret et al., 2011).

DCD is a chronic disorder that remains through life; however, it is possible to minimize its impact with an early intervention (Camden, Wilson, Kirby, Sugden, & Missiuna, 2015). For that it is crucial to recognize and to diagnose DCD early in life.

Although the increased interest within the scientific community in this theme, DCD frequently remains undiagnosed. A possible reason for this is the lack of knowledge on behalf of health professionals, teachers and family. A recent survey revealed that less that an half of the paediatricians knew about DCD (41%), and even less knew the secondary consequences of it; the percentages are even lower in teachers and parents, with 23% and 6%, respectively (B. N. Wilson, Neil, Kamps, & Babcock, 2013).

The MABC-2 battery test is one of the most employed to aid in the DCD diagnosis, allowing to identify and describe the motor impairment in children (Henderson & Sugden, 2007). The battery is composed of tests in three categories: manual dexterity (3 tests), aiming and catching (2 test), and static and dynamic balance (3 tests). Scoring the tests, the battery allows to determine if the child has probable DCD (total test score ≤56, percentile range ≤5); if the child is at risk in motor development (total test score between 57 and 67 inclusive, percentile range between 5 and 16 inclusive), which is a transition zone where the child does not have the disorder but has motor impairments; or if the child is in a typical motor development zone (total test score above 67, percentile range above 16). It is important to note that DCD should be diagnosed by a multidisciplinary team of professionals qualified to examine the specific criteria for the disorder (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012); if this does not occur we can only declare a probable DCD.

Along with the total score, the battery also classifies the child's motor performance by category, so we can find children with probable DCD but with a risk classification in one or more categories. Taking into account that DCD children are a heterogeneous group (Laurence Vaivre-Douret et al., 2011b), the possibility of discriminating the categories where the children have motor impairments is a strong point of MABC-2 (Henderson SE & Sugden DA, 2007).

The goal of the present study consists of identifying and characterizing the prevalence of probable DCD in three preschools of Rio Maior and São João da Ribeira, by using MABC-2 battery test.

2. Methods

2.1. Sample

The study took place in three preschools, two in the city of Rio Maior and one in the village of São João da Ribeira (belonging to Rio Maior County). The participants were included in the study after their parents signed the Informed Consent form.

Only children between 3 and 4 years were included, taking into account that the earlier the diagnosis and intervention the better the results (Bouwien C. M. Smits-Engelsman et al., 2013a). The children that violated the Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria for DCD e.g. with intellectual disability, visual impairment and neurological condition that affects movement were excluded (American Psychiatric Association, 2013).

From the 64 children, only 52 parents signed the Informed Consent, which represent an acceptance percentage of 81.25%. During the tests 2 children did not turn up, and 4 were excluded: 1 due to visual impairment (not corrected even wearing glasses), 2 did not give assent, and 1 due to signs of fatigue and demotivation during the tests. So, the final sample was composed of 46 children (see tables 3 and 4).

Table 3 – Sample characterization by age (decimal)

	N	Minimum	Maximum	Mean ± SD
Decimal age	46	3.4	4.4	3.9 ± 0.26

Table 4 – Sample characterization by sex

	Frequency	Percentage
Girls	25	54.3%
Boys	21	45.7%

2.2. Procedures

Before the application of MABC-2 it was necessary to get the authorization from the school and parents. The researcher established contact with the school centres through face-to-face meeting to explain the purpose of the study to the directors, and later via formal e-mail requesting authorisation. Afterschool approval, the Informed Consent was given to the parents to sign (see appendix 1).

The present study was accomplished in the following year of a funded project (ALENT-07-0262-FEDER-001883) which also addressed the issue of DCD, namely with the application of MABC-2 followed by intervention, which facilitated the acceptance by directors and parents.

After the MABC-2 battery application and classification, a document was elaborated by the child with the individual scores and delivered to their parents in a sealed envelope (see appendix 2). In the cases of the children that revealed one or more categories' classification of risk or probable DCD, a document was also added with suggestions for motor activities to apply at home (see appendix 3). These procedures were performed to enable parents to learn their child's classification and his/her impairments, so parents can be made aware of that matter. And also, to eliminate a weak point of the previous project mentioned by educators as the lack of a final information to parents. Several educators mentioned that parents would like to know their children's results.

2.3. Protocols

As mentioned before, the identification of children with probable DCD and at-risk was conducted according to the protocol of MABC-2, band 1 was used for the age group between 3 to 6 years (Henderson et al., 2007).

The first contact between researcher and the children was mediated by the respective educator who presented the researcher as a new teacher who will play with them. All test application was conducted in a game mode, to promote children acceptance and minimize shyness. In all cases, the researcher tried to play with the child to create a bond and empathy before applying the tests.

In cases where the child was introvert, the researcher invited an auxiliary or the educator to assist the games/tests, so that the children could feel more comfortable. If this did not work, the researcher invited a parent to participate. The first situation occurred 4 times and the latter once. For the latter, a day and time were scheduled so the mother could assist in the games. If at any moment the child asked for a classmate's help, the researcher allowed him/her to pick a friend to assist the games, explaining to the classmate that he/she could not interfere or talk while performing the games.

2.4. Statistical Analysis

Statistical significance was analysed through the use of the Statistical Package for Social Sciences (SPSS) version 23.

Descriptive statistics were performed by, mean and standard derivation, to characterize the sample, relative to age, MABC-2 scores by children groups, and MABC-2 scores by category. Frequency tables were also performed with prevalence of children's group, manual preference, and children classification distribution by category.

. The Kruskal Wallis test was used to verify whether category results differed among groups. To compare the categories' results group by group, the U-Mann Whitney test was used, with Bonferroni correction and effect size calculation. To determine within each groupwhether the categories' results were different, the Friedman test was used. Alevel of significance of *p*=0.05, two-tailed was adopted.

3. Results

The chronological age normally consists ofan independent variable, however for the present study our purpose did not reside in chronological age but in motor age. So, we did not consider it as an independent variable. This decision can be justified by the battery tests on their own. If MABC-2 considers age bands, and if band 1 is aimed at 3 to 6 year-olds, we supposed that this means that inside this band the differences in age are insignificant. To prove this, the chronological age is not the variable responsible for MABC-2 results we present bellow, in Figure 12, a graphic image of MABC-2´s percentile total score by chronological age. As we can tell, there is no clear tendency for data, like a regression line.

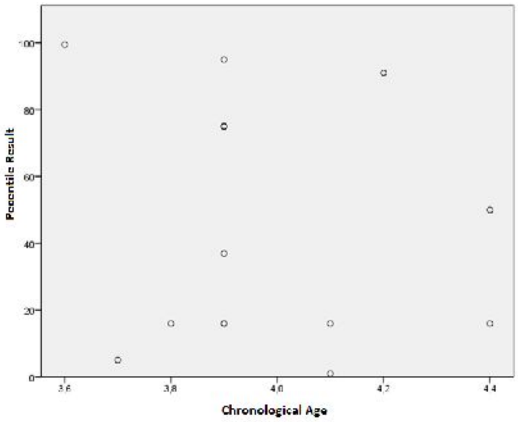

Figure 12 – MABC-2 results (percentile total score) by chronological age (in decimal age)

After applying the tests it was found that 37 children had typical motor development (80.4%), 7 were classified as at-risk of developing DCD (15.2%), and 2 as with probable DCD (4.4%) (see table 5). In the risk group, 4 children were girls and 3 were boys; in the p-DCD group 1 child was a girl and the other was a boy.

Table 5 – Sample characterization (number of cases and percentage) according MABC-2 classification (typical, risk, probable DCD), and by gender

	Male (n=21)	**Female** (n=25)	**Total** (n=46)
Typical	17 (81%)	20 (80%)	37 (80.4%)
Risk	3 (14.3%)	4 (16%)	7 (15.2%)
DCD	1 (4.8%)	1 (4%)	2 (4.4%)

Considering all the samples, the proportion found between dexterous and left-handed is close to 90% and 10%, respectively, as found in literature (Fonseca, 2011; Perelle & Ehrman, 2005), with effective values of 89.1% and 10.9%, respectively (see details in table 6). In the risk group all children were dexterous, and in the DCD group all children were left-handed.

Table 6 – Sample characterization according to preferred hand, by group (Typical, At risk, DCD) and gender

	Gender	Dexterous	Left-handed
Typical	**Male** (n=17)	15 (88.2%)	2 (11.8)
	Female (n=20)	19 (95%)	1 (5%)
At Risk	**Male** (n=3)	3 (100%)	0
	Female (n=4)	4 (100%)	0
DCD	**Male** (n=1)	0	1 (100%)
	Female (n=1)	0	1(100%)
Total	**Male** (n=21)	18 (85.7%)	3 (14.3%)
	Female (n=25)	23 (92%)	2 (8%)
	All (n=46)	41 (89.1%)	5 (10.9%)

It is possible for a child to have a total classification of having a typical development, but being in the risk zone or in probable DCD zone in some of the MABC-2 test' categories. In this study, several cases of children considered to be globally typical were found, who revealed at-risk or probable DCD, as we can see next: one typical child with at- risk classification in manual dexterity; five with at- risk classification in aiming and catching; one with probable DCD in aiming and catching; and four with at- risk classification in balance, see Table 7.

Inside the risk group, children with typical classification in some categories were found: two children with typical classification in aiming-catching and balance categories; two children with typical classification in manual dexterity and balance categories; one child with typical classification in balance category; one child with typical classification in manual dexterity category, and one child with typical classification in aiming-catching category. Inside the probable DCD group, a child with at- risk classification in manual dexterity and balance categories was identified.

Table 7 – Distribution (frequency and percentage) of children´s total and partial classifications at the MABC-2 test, by group and gender

MABC-2 test classification				**Gender**		**Total**
Total	**Manual dexterity**	**Aiming and catching**	**Balance**	**Boy**	**Girl**	
Typical	Typical	Typical	Typical	14 (30.4%)	12 (26.1%)	26 (56.5%)
Typical	Risk	Typical	Typical	1 (2.2%)	0	1 (2.2%)
Typical	Typical	Risk	Typical	2 (4.3%)	3 (6.5%)	5 (10.9%)
Typical	Typical	Typical	Risk	0	4 (11.1%)	4 (8.7%)
Typical	Typical	DCD	Typical	0	1 (2.2%)	1 (2.2%)
Risk	Risk	Typical	Typical	2 (4.3%)	0	2 (4.3%)
Risk	Typical	Risk	Typical	0	2 (4.3%)	2 (4.3%)
Risk	Risk	Risk	Typical	0	1 (2.2%)	1 (2.2%)
Risk	Typical	Risk	Risk	0	1 (2.2%)	1 (2.2%)
Risk	Risk	Typical	Risk	1 (2.2%)	0	1 (2.2%)
DCD	Risk	DCD	Risk	0	1 (2.2%)	1 (2.2%)
DCD	DCD	DCD	DCD	1 (2.2%)	0	1 (2.2%)
Percentages of the total sample						

The findings of this study, indicate that children with typical development revealed a mean percentile score of 69(±24), whose value is well above percentile 16, which separates typical motor development from at-risk. The group at risk presented a mean value near the limit of a typical motor development (see table 8), as found in a previous study (Arrais, 2014) with a larger sample from the same geographic area.

Table 8 – Distribution of MABC-2 total, standard and percentile scores (mean and standard deviation) by children's groups (Typical, At Risk, DCD)

	Typical (n=37)	**At Risk** (n=7)	**DCD** (n=2)
Total score	87.5 ± 10.5	64.9 ± 2.3	45.5 ± 9.2
Standard score	12.2 ± 2.8	6.9 ± 0.4	4 ± 1.1
Percentile score	69 ± 24	15 ± 2.6	3 ± 2.9

Table 9 also shows percentile scores by category for each group. In typical and probable DCD groups the category with the lowest score was aiming and catching (AC), and at-risk group was in balance.

Table 9 – MABC-2 percentile scores (mean and standard deviation) by category (MD, AC, B) and children's groups (Typical, At Risk, DCD)

	MD	**AC**	**B**
Typical (n=37)	68.2 ± 22.3	58.8 ± 30.7	65.6 ± 30.2
At Risk (n=7)	24.7 ± 19	27 ± 20.3	23.9 ± 11.5
DCD (n=2)	10.5 ± 7.8	5 ± 0	5 ± 5.7
H* (2), *p	16.267, <0.001	10.833, <0.01	14.179, ≤0.001
MD – manual dexterity; AC – aiming and catching; B – balance; *H*- Kruskal-Wallis test			

Through the Kruskal Wallis statistical test, it was possible to verify that within the same category, groups were considerably different in all categories: manual dexterity, aiming and catching and balance.

To compare groups within the same category, the Mann -Whitney U test was applied with Bonferroni correction, these being notably different where *p* should be less than 0,017. The effect size calculaton was also performed, in order to evaluated the power of the statistical result, r=0.1 small effect, r=0.3 medium effect, r=0.5 large effect (Field, 2010). Between DCD and typical groups, we found the following results: manual dexterity *Z*=-2.316, *p*=0.021, *r*=0.37; aiming and catching *Z*=-2.24, *p*=0.025, *r*=0.359; and, balance *Z*=-2.277, *p*=0.023, *r*=0.365. Between at- risk and typical groups: manual dexterity with Z=-3.478, *p*=0.001, r=0.524; aiming and catching with Z=-2.5, *p*=0.012, r=0.377; and balance with Z=-3,136, *p*=0.002, r=0.473. Between DCD and at-risk groups: manual dexterity with Z=-1.283, *p*=0.2, r=0.428; aiming and catching with Z=-2.103, *p*=0.035, r=0.701; and balance with Z=-1.826, *p*=0.068, r=0.609. The analysis did not identify significant differences between DCD and typical groups, or between DCD and at-risk children, only a tendency; however, we detected significant differences between at- risk and typical groups in all categories; probably, due to the size of the samples. This argument is supported by effect size values which are bigger in the comparisons between risk-typical than between DCD-typical groups.

To compare different category results within the same group the Friedman test was used. This test revealed no significant differences between categories, for typical children results obtained were χ^2=1.145, *p*=0.564; for at risk χ^2=0.074, *p*=0.964; and for DCD χ^2=2, *p*=0.368.

4. Discussion

The results in this study show a percentage of 4.4% for probable DCD, slightly lower than 5-6% referred in previous studies (Vaivre-Douret, 2014; Vaivre-Douret et al., 2011), probably due to the sample size. Similarly to Cairney et al. (2008) study, it was not found a higher prevalence of probable DCD in boys.

According to literature, it was found a prevalence of left-handedness in probable DCD children (Cairney et al., 2008; Flouris et al., 2005), which did not occur in typical or at -risk groups. In the literature we can find several possible explanations for the predominance of left-handedness, like learner behaviour, neurochemical variations during prenatal stage or genetic factors (Flouris et al., 2005). However, it is consensual that left-handiness is linked with various neurological and behavioural problems (Cairney et al., 2008). In children, there is a reported association between left-handedness and developmental disorders, including language, sensory and motor impairments and also socioemotional and psychiatric problems (Coren & Bishop, 1993). This study reinforces the prevalence of left-handedness in DCD, however the reason for this is still not clear, therefore, more investigation in this field is needed.

The prevalence of children at risk of developing DCD was of 15.2%, about the triple of the DCD prevalence. So, it's crucial to detect not only the DCD children but also the ones that, despite not suffering from this disorder, have motor impairments. An early identification makes an early intervention possible and, consequently, better results (Bouwien C. M. Smits-Engelsman et al., 2013a). The possibility of identifying children at risk of developing the disorder is a strong point of MABC-2 and should be considered in future studies with 3 year-olds.

Apart from the final classification of typical, at- risk and probable DCD, the MABC-2 battery test allows us to discriminate in which categories the child has an impairment (Henderson & Sugden, 2007). Our findings confirmed the existence of children classified as typical with classifications of at- risk and probable DCD, but only in part of the categories: one child in manual dexterity risk, five in aiming and catching risk, one in aiming and catching probable DCD, and four in balance risk.Moreover, with regard to category percentiles' scores we verify that the least scored were aiming and catching for typical motor development and probable DCD groups, and balance for at- risk group. Within the typical group, these percentiles' scores and the highest prevalence of non-typical classification in aiming-catching and balance categories, can probably result from less motor practice in activities involving these tasks. Contrasting with a higher incidence in tasks like drawing letters, lines and numbers that are stimulated to promote a better approach to cognitive learning in elementary school, and further afford the manual dexterity, compared to other studied categories.

The possibility of identifying which categories children have impairments in is another strong point for MABC-2 which can also be applicable and relevant for the intervention. If we could not only divide children by the total score but also, analyse more deeply and see in which areas they have a real impairment, we would be able to mould and adjust our intervention for better results and greater success. It is worth noting, that DCD children are a very heterogeneous group (Vaivre-Douret et al., 2011); so, this may not only be a tool, to evaluated and support DCD diagnosis, but also an instrument to support intervention.

The limitations of the present study reside mainly in the sample, which is small, and we used a kindergartens' convenience sample; so, it did not include children who do not attend kindergartens. The researcher who applied MABC-2 battery test was not blind to the study purpose, which is a threat to the internal validity of the study. In future studies, ideally a random, bigger and more representative sample should be used, with researchers that apply the battery blind to study purpose; so we coulddraw conclusions for the sample's population and eliminate internal threats.

5. Conclusions

Overal, the at -risk children revealed an incidence 3.4 times bigger than p-DCD children, and this fact should make us aware of the importance of identifying not only p-DCD children but also, at- risk children.

According to literature it was verified a prevalence of left-handedness in probable DCD children (Cairney et al., 2008; Flouris et al., 2005), nevertheless, our experimental design fails to prove why.

The least scored categories were aiming and catching for typical and probable DCD children, and balance for at- risk children. These results and a higher prevalence of non-typical classifications, inside the typical group, in the same categories, may result from a lesser involvement in aiming-catching and balance activities, contrasting with a greater incidenceon manual dexterity activities, in order to prepare children for elementary school.

The possible identification of children at risk, as well as which categories children have impairments in, are strong points of the MABC-2 battery test, which may be useful to support a more adjusted intervention.

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Chapter IV

Postural Control in Preschool Children with Developmental Coordination Disorder, in sitting position during a functional task

Abstract

The developmental coordination disorder (DCD) is a motor disorder without neural compromising that affects 5-6% of children within school-age (Vaivre-Douret, 2014; Zwicker, Missiuna, Harris, & Boyd, 2012). One of the most prevalent problems is the postural control (PC) deficit which affects 73 to 87% (Macnab, Miller, & Polatajko, 2001).

Being an idiopathic disorder which one of the possible causes is a sensory integration problem (Vaivre-Douret et al., 2011), to analyse PC it's necessary to evaluate the quality of movement and how its processed through time. Nonlinear methods can provide information about small improvements and alterations in PC over time (Deffeyes, Harbourne, DeJong, et al., 2009).

The present research seeks to study PC in p-DCD children, risk and typical in a sitting position during a functional task, in the following order: i) just being seated; ii) same as in i), but with the eyes closed; iii) the child observed a modulation of a ball with plasticine; iv) the child moulded the plasticine by himself; v) same as in iii) with eyes closed.

P-DCD children were tendentially less recurrent (lowest REC), less periodic (lowest meanline) and also simpler and more regular (lowest entropy and highest SampEn). These children oscillated more and faster in conditions with visual information (VI); with a visual focus they had more stability (lowest LyE) and oscillated less and slowler campared to the baseline, possibly, the ballfunctioned as a visual anchor; without (VI) they reduced their oscilations and velocity for both points and become less recurrent, periodic, stable and simpler, possibly freenzing more freedom degrees in order to respond to absence of external information. P-DCD seem to be more dependent on external stimulus like VI to auto organize their own balance. The greater the task's complexity, the lesser and slower their oscillations were but also more recurrent and periodic.

Despite oscillating more and faster in all conditions and being tendentially more recurrent and periodic, at -risk children revealed a behaviour pattern similar to typical in both points. Possibly due to being in a transition zone at- risk children oscillate more and faster searching for motor solutions but also in a more recurrent and periodic manner to compensate their difficulties.

P-DCD, at- risk and typical children reveal the same mode of action without visual information, less and slower oscillations. Most likely, the problem with p-DCD is not in terms of motor control, but on perception-action cycles' effectivness; and, where stimulation must be focused.

The nonlinear methods can be used in PC study in DCD children, however it's crucial to find a more suitable strategy for data collection in order to obtain time series of at least 2000 data.

Key-words: Postural control, DCD, children, sitting, functional task

1. Introduction

The developmental coordination disorder (DCD) is a motor disorder without neural compromising identified and recognized by the Diagnostic and Statistical Manual of Mental Disorders (DSM) (American Psychiatric Association, 2013). DCD affects 5-6% of children within school-age, and it is referenced for impairment in fine and/or global coordination development, difficulty in motor control and learning, and in the acquisition of new motor skills (Vaivre-Douret, 2014; Zwicker, Missiuna, Harris, & Boyd, 2012).

These difficulties in motor control and learning are expressed in many ways, such as a delay in achieving motor milestones, clumsiness, poor balance, difficulties in writing and drawing (Chang & Yu, 2010), poor postural control (Geuze, 2005), and difficulties in space and temporal organization (Wilson & McKenzie, 1998). Affecting the daily life of the children, DCD evolves to bring about additional consequences such as academic delay or social isolation (CanChild, 2016; Joshi et al., 2015a; Vaivre-Douret, 2014). For example, a child who cannot maintain his posture while sitting on a chair and simultaneously has difficulties in drawing letters correctly, will be a child that is neither focused on the lesson nor on the teacher but simply on trying to control his/her posture and on drawing the letter, resulting in a progressive and cumulative academic impairment.

The DCD’s ethology is still not clear, one of the possibilities consists of a sensory integration deficit (Vaivre-Douret et al., 2011). Motor impairment in DCD children varies in severity and nature (Vaivre-Douret, 2014), these children are a heterogeneous group, as they can reveal only part of the symptoms as opposed to all simultaneously; e.g., the child can reveal balance problems but no visual and spatial difficulties, or vice versa (Vaivre-Douret et al., 2011).

DCD is a chronic disorder, the difficulties remain during puberty and adult life; it does not simply disappear as time goes by (Camden et al., 2015; Cousins & Smyth, 2003). An early diagnosis, accompanied by an early intervention, may help to minimize the negative effects of DCD and to enhance life quality during infancy and adult life (Smits-Engelsman et al., 2013).

One of the most employed tools to diagnose DCD is the MABC-2 battery test, which allows to identify and describe the motor impairment in children (Henderson & Sugden, 2007). By scoring the tests, the battery helps to identify if the children as probable DCD; is at risk of developing DCD, that’s a transition zone where the child does not have the disorder but has motor impairments; or, he/she is in a typical motor development zone.It is important to note that DCD should be diagnosed by a multidisciplinary team of professionals qualified to examine the specific criteria for the disorder (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012), if it does not occur we can just talk about a probable DCD.

To provide the best possible intervention and therapy, first, it is necessary to understand the disorder in depth and how it triggers the problem that we want to lessen. One of the most prevalent problems is the postural control deficit, which affects 73 to 87% of the DCD children (Macnab, Miller, & Polatajko, 2001). This impairment affects the daily life of the child since it is crucial for all daily tasks, like walking, running, playing, putting the groceries on a shelf, picking something up from the ground, reacting to an unexpected disturbance like avoiding an obstacle such as a bike, and so many other tasks and activities.

To understand more deeply how balance in DCD children evolves and differs from typical it is necessary to disturb the system and force it to reorganize itself, to analyse it and understand how it reacts. In order to analyse PC closer to the children's daily life it would be interesting to introduce a functional taskwhich they can replicate in their daily life (Donker et al., 2008; Mercê et al., 2016).

Bearing in mind that the DCD children could have a sensory integration deficit, the problem in PC could reside in its own process. So, to study PC it should be used methods that in spite of quantifying movement, they can also analyse its quality and how the PC evolve over time. Nonlinear methods have recently proven that they can provide information that other methods cannot, namely, about the quality of movement and how the movement is controlled by the system as time goes by (Costa, Batistão, & Rocha, 2013). These methods are sensitive to small improvements and alterations in postural control over time and can also reveal significant differences between typical and delayed development in children with motor disabilities, e.g. cerebral palsy (Deffeyes, Harbourne, DeJong, et al., 2009; Deffeyes, Harbourne, Kyvelidou, et al., 2009; Kyvelidou, Harbourne, Shostrom, & Stergiou, 2010).

The present researchaims to analyse and compare PC in p-DCD, risk and typical children during a functional task in sitting position. We hope that this analysis leads to clues for a most suitable intervention in the improvement of PC in p-DCD children. The study conditions were defined based on leads left by other authors, namely the introduction of a visual focus (Donker et al., 2008), the use of a functional task (e.g. Cravo, 2012; Mercê et al., 2016), and the eyes closed (e.g. Donker et al., 2008; Geuze, 2005). Children performed the following conditions: i) just being seated; ii) same as in i), but with the eyes closed; iii) observing a process of the modulation of a ball with a piece of plasticine, by the experimenter in front of her/him; iv) moulding, a ball by himself with a piece of plasticine; v) same as in iv), but with the eyes closed.

Considering the necessity to evaluate the quality movement, besides the linear methods including total distance, amplitude and velocity for the points in study, it was also used nonlinear methods including recurrence quantification analysis (RQA), laminarity, Lyapunov exponent (LyE) and also sample entropy (SampEn). RQA, this is a non-linear and multidimensional technique that reconstructs the temporal series in the space to verify the recurrent points also knownas neighbour points. The basis of this analysis consists of rebuild a sphere of radius *r* centred on a point *x(i)* in the reconstructed space, and counting the points that fall inside the radius (Riley, Balasubramaniam, & Turvey, 1999). This technique provides us with several variables that can describe the system, allowing its analysis, they are: i) percent recurrence (%RECUR or %REC) – percentage of recurrent points, points that fall in the radius; ii) percent determinism (%DET) – percentage of points that form diagonal lines, these diagonals indicate that the system is revisited in the same region of the attractor, %DET reflect the degree of determinism; iii) maxline – the biggest length of the diagonal lines, this is a measurement of the global stability; iv) meanline – mean of the diagonal lengths, a bigger meanline implies that the system is, in mean, enter in longer deterministic states, so meanline consists of a periodicity measurement; iv) entropy – measurement of the complexity system, the higher the entropy the higher thecomplexity (Riley et al., 1999; Webber & Zbilut, 2005).

Laminarity evaluated the amount of recurrent points which form vertical lines. These vertical lines or diagonals evidence a determinist system and nonlinear, to make it simple, to form lines the system’s orbit in phase space is revisiting the same region once and again, so it is revisiting an attractor (Palmieri & Fiore, 2009). Laminarity evaluated the amount of these vertical lines to understand the intermittency of the system, a system with a higher laminarity is a more interment system. According to maxline for diagonal lines we can also find Vmax to the biggest length of vertical lines.

The Lyapunov exponent (LyE) is another nonlinear technique that can detect the presence of chaos in the system and has been used to analyse biological systems. This variable measures the rate of how nearly orbits converge or diverge in the state space. In periodic signals, the orbits will not diverge or converge so the LyE would be 0 because the trajectories in the state space are completely overlapped. If the orbits diverge, the system is exploring an exponential growth, the LyE would be superior to 0. If the orbits converge the system is exploring an exponential decay, the LyE would be inferior to 0. A positive LyE indicates chaos in the system, the larger the LyE the bigger the instability (Harbourne & Stergiou, 2003).

In order to overcome the approximate entropy limitations, it was developed the SampEn (Richman & Moorman, 2000). This is like an improvement in relation to ApEn, which despite being used in chaotic systems, did nott indicate determinist chaos in the system, only if the data are predictable or not, a lower entropy means more regularity in the system. For a correct function of SampEn, the data should be larger than 200, the longer the better, and we could not compare time series with different lengths (Yentes et al., 2013).

2. Methods

2.1. Sample

The study took place in three Portuguese kindergartens, two in the city of Rio Maior and one in the village of São João da Ribeira (belonging to the Rio Maior County). The identification of children with probable DCD and at- risk was conducted according to MABC-2 protocol; and identified by an expert panel of three experts in motor behaviour. It was used the band 1 for the age group of 3 to 6 years (Henderson et al., 2007). It was conducted the informed consent of the parents and the assent of the participants, being that the will of children was always respected. Two children were identified with probable DCD, and, seven as at risk (see Chapter III). From the seven at- risk, children, identified by MABC-2, two did not participate in the present study, one for not attending the data collection, and the other for not wanting to participate (according to assent principle).

For the present study, 14 children were included both gender, and a mean age of 3.98 ± 0.24 years old. For the two probable DCD and for the five at- risk children, 7 children with typical motor development were paired (see tables 10 and 11). The pairing was made by gender, age, kindergarten, and MABC-2's scores, being that all typical children had a percentile score higher than 25 (Adams, Ferguson, Lust, Steenbergen, & Smits-Engelsman, 2016).

Bearing in mind that the earlier the intervention and diagnosis the better the results, it was only considered children with 3 and 4 years (Bouwien C. M. Smits-Engelsman et al., 2013a). Children that violated the criteria of DSM-IV for DCD, like intellectual disability, visual impairment and neurological condition that affects movement,were not included (American Psychiatric Association, 2013).

Table 10 – Sample characterization by age

	N	Minimum	Maximum	Mean ± SD
Decimal age	14	3.6	4.4	3.98 ± 0.24

Table 11 – Sample characterization by sex

Children Group	Sex		Total
	Female	Male	
Typical	4	3	7
At Risk	3	2	5
p-DCD	1	1	2
Total	8	6	14

2.2. Procedures

In order to attain authorization from kindergartens and parents, the researcher established a preliminary contact by face-to-face meeting with the directors, and later via formal e-mail requesting authorisation. After acceptance from the school director, it was conducted the informed consent to the parents (see appendix 1).

The present study was accomplished in the following year of a funded project (ALENT-07-0262-FEDER-001883) which also addressed the issue of DCD, namely with the application of MABC-2 followed by intervention, which facilitated the acceptance by directors and parents. Before data collection, the researcher talked to the children explaining that they would play a few games with some lights (leds) on their clothing, like an “astronaut or a super hero”. If the children did all games and had a good behaviour, they would receive a gift, a spider man or a princess crayon. Before starting, the researcher explained and reinforced to the child that he/she did not have to think if he/she was doing well or not, what mattered was to simply dothe task. The children were already familiarized with the researcher, given that the same person had applied the MABC-2 battery to them during the cited project. All data collection was conducted in a game form, to promote the children’s acceptance and minimize eventual withdrawals.

2.3. Tasks

Childrencompleted five tasks (conditions), always in the following order: i) just being seated (SEO), the child was seated on a bench forming a 90° angle at the knee, with both feet on the floor, without restrictions referring to arms and hands positions; ii) same as in i), but with the eyes closed (SEC), to blindfold the children it was used a cloth; iii) the child observed a modulation of a ball with plasticine made by the researcher in front of him/her and at his/her eye level (SD), slowly and roughly; iv) the child moulded the plasticine byhimself to make a ball (DEO) no restriction was made to time, arms and hands movements, and using the legs to support the action (Mercê et al., 2016) ; v) same as in iv), but with the eyes blindfolded (DEC), see Figure 13.

Figure 13 – Experimental setup and conditions, from i) to v) (left to right)

With different conditions we pursued different stimulation purposes. In condition ii) we removed visual information, with the purpose of having information on the role of vision in a baseline task, simply being seated. With condition iii) we introduced a functional visual focus (e.g. Donker et al., 2008); different from condition i), in this condition the visual information was necessary to observe an action performed by another person, parallel to its role in postural control. In condition iv), the child had to use his/her visual information to complete a functional task (e.g. Cravo, 2012), but, simultaneously, he/she needed to control his/her posture in order to support the task in hand, possibly with an additional appeal to proprioceptive information. Finally, in condition v), with the removal of visual information, the child had to resort to proprioceptive (and haptic) information, in order to preserve postural control and to detect the evolution of the task to be completed in plasticine moulding (Table 12).

Table 12 – Study conditions and purpose

Condition	**i)**	**ii)**	**iii)**	**iv)**	**v)**
Description – Abbreviation	Sitting eyes open - SEO	Sitting eyes closed - SEC	See doing – SD	Doing eyes open - DEO	Doing eyes closed - DEC
Stimulus	Baseline	No VI	VF	FT	FT and No VI
No VI - No visual information; VF - visual focus; FT - functional task					

The sitting position for data collection, and no restriction for arms and hands positions or leg support to mould was conducted according to a previous study with cerebral palsy (Mercê et al., 2016).This methodologic approach was taken in order to make it possible to replicate the present study in future with cerebral palsy (CP). It will be very interesting to understandwhether children in CP behave with the same pattern as DCD or, on the other hand, reveal a pattern of their own.

The order and the preservation of the sequence of the tasks were based on the progressive difficulty of them, and on the need to initially have baseline references unaffected by functional task interferences. To see what was meant to be done, before doing it, also helped the children to understand the task in hand. We could have alternated the order of presentation of conditions iv) and v), however, we were afraid that the inversion of this order would be too complex for the children with probable DCD, leading them to avoid the task or to abandon the study.

2.4. Data Collection

We collected data from the following anatomic points: vertex (V, point that represent the head movements), and cervical 7 (C7, that represent the trunk movements). Two high definition cameras, Casio model Exilim Ex-ZR200, at 240 Hz, were placed perpendicularly, one behind and another beside the children (Payton & Bartlett, 2007). The points were identified using led markers, to increase their contrast in order to facilitate kinematic analysis; windows and light sources were partially closed. When children used white or bright clothes the researcher dressed them with a dark cloth.

The filming in conditions i), ii) and iii) had a 30 second duration, the maximum time for balance tests in MABC-2 (Henderson et al., 2007). In conditions iv) e v) the filming lasted the time that the child took to create the plasticine ball. The beginning of the data collection matched when the child grabbed the ball, and the end matched when the child informed the researcher that he/she had finished it.

2.5. Data Treatment

Kinematic analysis was performed with Ariel Performance Analysis System (APAS), version 2003, and nonlinear analysis was performed through Matlab, version 2005.

All-time series was reduced to a least a common denominator, despite the target of data collection having been 30 seconds, in some cases, children did not take this long to complete the task. So, it was selected the smaller time series, 3600 data, and it was considered just the

3600 first data off all- time series, so all of them could be under the same conditions (Yentes et al., 2013).

In order to identify the data ideal frequency, it was performed the power spectrum in time series (Kyvelidou et al., 2013), this was identified at 60 Hz, so it was proceeded to a down sample of data obtaining time series of 900 numbers, all of these proceedings were performed in Matlab.

For nonlinear treatmentthere were not applied any filters in order to not alter nonlinear measurements (Deffeyes, Harbourne, DeJong, et al., 2009). For linear treatment it was applied a filter with cut=12 and n=4. All linear and nonlinear variables were performed in Matlab.

2.6. Statistical Analysis and Error Measurement

For statistical analysis and error measurement it was used the Statistical Package for the Social Sciences (SPSS) version 23.

APAS application error was measured. The dynamic error was considered for each point, V and C7, and for each motion plane, X for frontal, Y for transverse and Z for sagittal. To evaluate the dynamic error, it was performed twice the automatic digitalization for the same data with the same volume calibration scanning. The displacement outputs of the two digitalisations were analysed with descriptive analysis calculating the mean, standard deviation and mean differences in order to obtain the average error (Table 13). It was also performed the inter correlation coefficient (ICC), that is a statistic technique which measures the values reliability of two or more measures, the ICC values less than 0.5 are considered to be poor, between 0.5 and 0.75 moderate, between 0.75 and 0.9 good, and greater than 0.9 excellent (Koo & Li, 2016). In present data it was verified 1 moderate ICC value, 1 good and 4 excellent. The transverse plan was the less reliable with moderate and good values, while frontal and sagittal planes revealed excellent values (Table 14).

Table 13 – Average Error for points and motion planes, displacment in mm

Point / Motion Plane	Mean		Standard Deviation		Average Error
	1st	2nd	1st	2nd	
C7 / X	521.34	522.83	3.46	3.45	-1.50
C7 / Y	606.08	602.96	3.21	3.22	3.12

C7 / Z	576.31	575.91	14.77	14.81	0.40
V / X	496.61	498	5	5.03	-1.39
V / Y	817.06	814.59	3.92	3.95	2.47
V / Z	511.01	510.15	21.82	21.88	0.86

Table 14 – ICC for points and motion planes

		Motion Planes		
		X	**Y**	**Z**
Points	**C7**	0.914	0.679	1
	V	0.963	0.836	0.999

For data analysis it was performed descriptive statistics with calculation of mean and standard derivation to characterize the sample, linear and nonlinear data. For both linear and nonlinear data to compare the results between groups for the same condition and point, the statistical test, Kruskal-Wallis test, was applied. Bonferroni correction was considered and a level of significance of p=0.05, two-tailed was adopted. For nonlinear measurements tendency tables were also performed to identify tendencies.

3. Results and Discussion

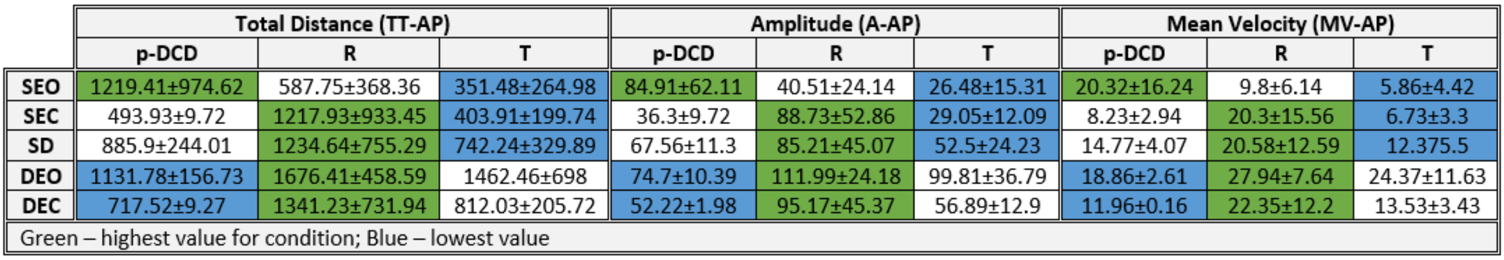
No significant differences werefound between groups for the same condition and point studied, we can find the Kruskall Wallis testresults in table 15 below, due to the Bonferroni correction for being significantly different *p* should be less than 0,01.

With descriptive statistics we analysed the axis of anterior-posterior movements (Apthorp, Nagle, & Palmisano, 2014) for total distance (TT-AP), the antero-posterior (A-AP) amplitude, and antero-posterior mean velocity (MV-AP); by group, anatomical point and condition (tables 16-19). For a more intuitive reading and data analyses, some values are highlighted, the green represents the higher value and the blue represents the lower value.

Table 15 – Comparisons for linear data between groups for the same condition and point

Point	Condition	Total Distance (TT-AP)		Amplitude (A-AP)		Mean Velocity (MV-AP)	
		H(2)	*P*	*H*(2)	*p*	*H*(2)	*p*
V	SEO	5.15	0.075	4.033	0.133	5.180	0.075
	SEC	6	0.050	8.501	0.014	6	0.050
	SD	1.187	0.552	1.494	0.474	1.187	0.552
	DEO	0.821	0.663	1.885	0.390	0.821	0.663
	DEC	3.159	0.206	0.168	3.157	0.206	3.159
C7	SEO	6.913	0.032	6.913	0.032	6.913	0.032
	SEC	2.976	0.226	3.571	0.168	2.976	0.226
	SD	2.162	0.339	3.021	0.221	2.162	0.339
	DEO	0.05	0.975	0.501	0.778	0.05	0.975
	DEC	3.113	0.211	7.548	0.023	3.113	0.211

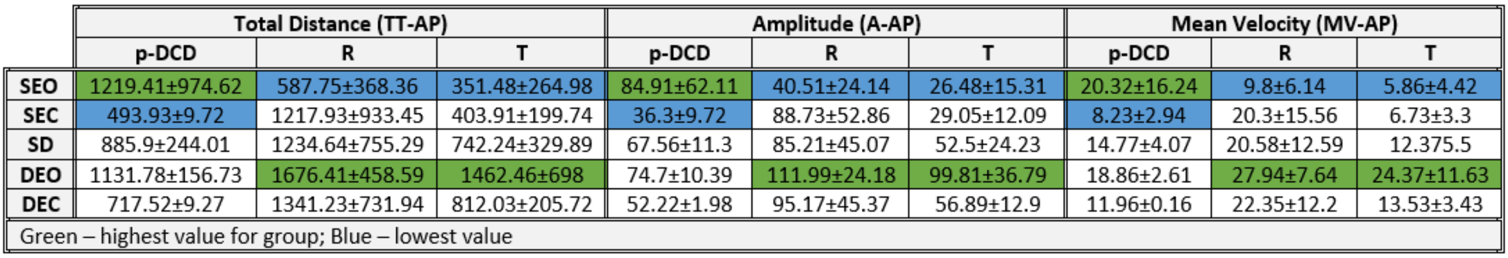
Table 16 – Descriptive statistics of posturography variables for vertex, values highlighted for highest (green) ad lowest (blue) values for the same condition between groups



	Total Distance (TT-AP)			Amplitude (A-AP)			Mean Velocity (MV-AP)		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	1219.41±974.62	587.75±368.36	351.48±264.98	84.91±62.11	40.51±24.14	26.48±15.31	20.32±16.24	9.8±6.14	5.86±4.42
SEC	493.93±9.72	1217.93±933.45	403.91±199.74	36.3±9.72	88.73±52.86	29.05±12.09	8.23±2.94	20.3±15.56	6.73±3.3
SD	885.9±244.01	1234.64±755.29	742.24±329.89	67.56±11.3	85.21±45.07	52.5±24.23	14.77±4.07	20.58±12.59	12.375.5
DEO	1131.78±156.73	1676.41±458.59	1462.46±698	74.7±10.39	111.99±24.18	99.81±36.79	18.86±2.61	27.94±7.64	24.37±11.63
DEC	717.52±9.27	1341.23±731.94	812.03±205.72	52.22±1.98	95.17±45.37	56.89±12.9	11.96±0.16	22.35±12.2	13.53±3.43

Green – highest value for condition; Blue – lowest value

Table 17 – Descriptive statistics of posturography variables for vertex, values highlighted for highest (green) ad lowest (blue) values for the same group between conditions



	Total Distance (TT-AP)			Amplitude (A-AP)			Mean Velocity (MV-AP)		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	1219.41±974.62	587.75±368.36	351.48±264.98	84.91±62.11	40.51±24.14	26.48±15.31	20.32±16.24	9.8±6.14	5.86±4.42
SEC	493.93±9.72	1217.93±933.45	403.91±199.74	36.3±9.72	88.73±52.86	29.05±12.09	8.23±2.94	20.3±15.56	6.73±3.3
SD	885.9±244.01	1234.64±755.29	742.24±329.89	67.56±11.3	85.21±45.07	52.5±24.23	14.77±4.07	20.58±12.59	12.375.5
DEO	1131.78±156.73	1676.41±458.59	1462.46±698	74.7±10.39	111.99±24.18	99.81±36.79	18.86±2.61	27.94±7.64	24.37±11.63
DEC	717.52±9.27	1341.23±731.94	812.03±205.72	52.22±1.98	95.17±45.37	56.89±12.9	11.96±0.16	22.35±12.2	13.53±3.43

Green – highest value for group; Blue – lowest value

We can verify that for the vertex point, each group of children had the same pattern in the three variables (total distance, amplitude, mean velocity).

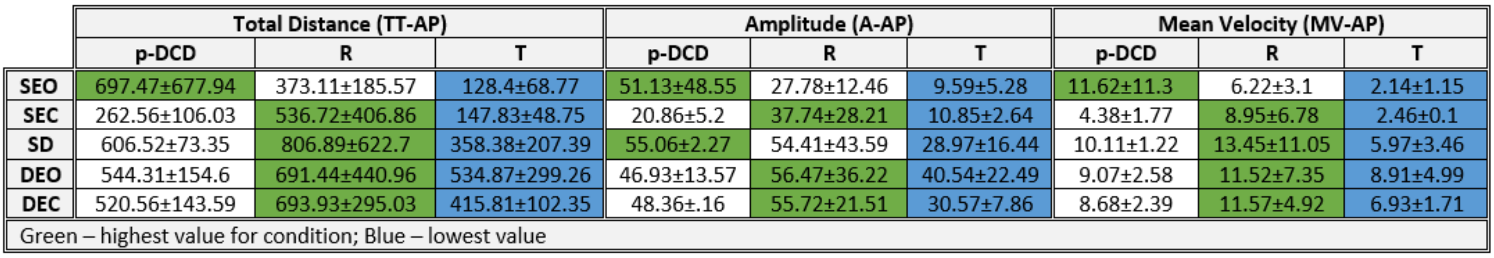
We can see in table 16, that for p-DCD the conditions envolving opened eyes (SEO and DEO) are the ones where they oscillated more (in total and in amplitude) and faster, contrasting to at- risk and typical children where despite oscillating more and faster in DEO they oscillate less and more slowly in SEO. Previous studies also revealed that CP children oscilate more in AP direction than typical ones during sitting position with eyes open (Kyvelidou et al., 2013). When a visual focus of attention was introduced (SD condition) p-DCD children oscillated less and more slowly compared to the baseline condition. Possibly, for p-DCD the focus on researcher manipulation worked as a visual anchor that in some way altered their postural control. However, this slowering is even more notorious when we remove visual information (SEC and DEC conditions). Passing the condition of SEO to SEC p-DCD children decrease their oscillations and velocity while at- risk and typical increase. Moreover, when we removed visual information during the task, passing of DEO to DEC, p-DCD children decrease their oscilations and velocity once more, even notecing that all groups that reduced these variables p-DCD are the ones that revealled the lowest values. In these cases, we cannot attribute changings in postural oscillations to an external visual focus, it is more like they freeze degrees of freedom, in order to respond to absence of external information; left to their internal information, these children became more conservative in their postural oscillations, as a necessary conditon to preserve postural stability and to perform the task in hand. The greater the complexity of the task, the lesser and slower the oscillations are. This hypothesis strengthens considering that p-DCD group is the one with the lowest oscillations and velocity during the tasks involving a functional task, DEO and DEC, the increase of task difficulty could lead once again to less and slower oscilations.

At- risk children revelead the highest TD-AP, A-AP and MV-AP, in all conditions, except for SEO.It could be that, the transition zone where at- risk children may be, in terms of postural control, forces them to try to explore solutions,which result in more and faster body oscillations (in total and amplitude).

Despiste being the group that oscillated more and faster under all conditions, at- risk children revealed a pattern of behaviour similar to typical. For the two groups in the simpler conditions, SEO e SEC, they oscillate less and more slowly, and for more complex conditions that envolve a functional task, DEO e DEC, they oscillate more and faster. It is interesting to note that, similarly to p-DCD, the remove of visual information during a functional task makes children oscillate less and more slowly, compared to the same condition with eyes open. So, generally speaking, DCD, at risk and typical developing children reveal the same mode of action when visual information removal occurs during a functional task, less and slower oscillations; thus, DCD children have the same qualitative postural mechanisms as typical children, although with different quantitative outputs. To behonest, it might mean that the problem of DCD children is not in modes of motor control, butin perception-action cycles' effectivness (Chen et al., 2014);, where stimulation must be focused.

The results for C7 marker are presented below, in tables 18 and 19.

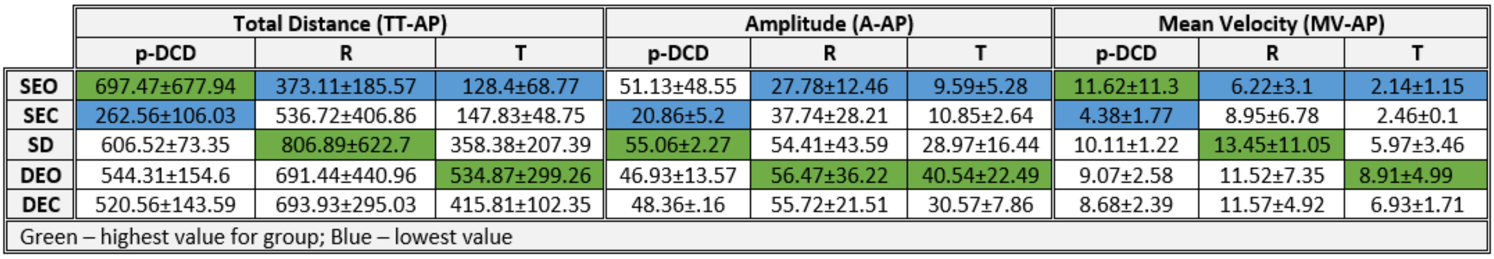
Table 18 – Descriptive statistics of posturography variables for C7, values highlighted for highest (green) ad lowest (blue) values for the same condition between groups



	Total Distance (TT-AP)			Amplitude (A-AP)			Mean Velocity (MV-AP)		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	697.47±677.94	373.11±185.57	128.4±68.77	51.13±48.55	27.78±12.46	9.59±5.28	11.62±11.3	6.22±3.1	2.14±1.15
SEC	262.56±106.03	536.72±406.86	147.83±48.75	20.86±5.2	37.74±28.21	10.85±2.64	4.38±1.77	8.95±6.78	2.46±0.1
SD	606.52±73.35	806.89±622.7	358.38±207.39	55.06±2.27	54.41±43.59	28.97±16.44	10.11±1.22	13.45±11.05	5.97±3.46
DEO	544.31±154.6	691.44±440.96	534.87±299.26	46.93±13.57	56.47±36.22	40.54±22.49	9.07±2.58	11.52±7.35	8.91±4.99
DEC	520.56±143.59	693.93±295.03	415.81±102.35	48.36±.16	55.72±21.51	30.57±7.86	8.68±2.39	11.57±4.92	6.93±1.71

Green – highest value for condition; Blue – lowest value

Table 19 – Descriptive statistics of posturography variables for C7, values highlighted for highest (green) ad lowest (blue) values for the same group between conditions



	Total Distance (TT-AP)			Amplitude (A-AP)			Mean Velocity (MV-AP)		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	697.47±677.94	373.11±185.57	128.4±68.77	51.13±48.55	27.78±12.46	9.59±5.28	11.62±11.3	6.22±3.1	2.14±1.15
SEC	262.56±106.03	536.72±406.86	147.83±48.75	20.86±5.2	37.74±28.21	10.85±2.64	4.38±1.77	8.95±6.78	2.46±0.1
SD	606.52±73.35	806.89±622.7	358.38±207.39	55.06±2.27	54.41±43.59	28.97±16.44	10.11±1.22	13.45±11.05	5.97±3.46
DEO	544.31±154.6	691.44±440.96	534.87±299.26	46.93±13.57	56.47±36.22	40.54±22.49	9.07±2.58	11.52±7.35	8.91±4.99
DEC	520.56±143.59	693.93±295.03	415.81±102.35	48.36±.16	55.72±21.51	30.57±7.86	8.68±2.39	11.57±4.92	6.93±1.71

Green – highest value for group; Blue – lowest value

As in vertex, in C7 marker the condition of SEO, which represents the baseline, promoted the biggest and fastest oscillations inside DCD group, and also the smaller and more slowly inside the at- risk and typical children. Looking at p-DCD group, the patterns identified in V are also present in C7, the condition where p-DCD oscillated less and more slowly was the SEC. Once again, when we removed visual information fromSEO to SEC, p-DCD began to oscillate less and more slowly when at- risk and typical increased their values. When we moved from DEO to DEC, p-DCD also reduced oscillations and velocity. This way, the visual information seems to be an important part of p-DCD postural control, when the difficulty increased with no visual information, it conducted to smaller and slower oscillations. Following this line of thought, it may be strange to see that DEC revealed bigger and faster oscillation than in SEC, supposedly doing a functional task blindfolded is harder that just being seated with eyes closed. Nonetheless, the data makes us believe that p-DCD are more dependent from external stimulus to self- organize their own balance. So, comparing DEC and SEC, in DEC despite supposedly being more difficult, p-DCD children had more external information with proprioceptive information about the mould of the ball, perhaps, the simple fact of doing a functional task can help them to manage their posture. If this is true, we should rethink our intervention in these children and focus on functional tasks.

At -risk and typical children also continued to reveal a similar pattern between them as shown in vertex, again, the conditions where children oscillated less and more slowly were the non-manipulation conditions, SEO and SEC. In conditions that involve the functional task, DEO e DEC, children started to oscillate more and faster, compared to the non-manipulation conditions. The removal of visual information, during the functional tasks also decreased C7 oscillations and velocity in typical children, and, at- risk children revealed similar values in DEO and DEC. Interestingly, at- risk children revealed the highest value for TD-AP and MV-AP in SD condition.

It is interesting to note, that for all groups, in all points and in all conditions the head, V, always oscillated more and faster than the trunk, C7.

So, it seems that the control of the head and the trunk is coordinated, in the sense of intersegmental coordination, independently of the pattern of motor development, which has an observable effect in the quantitative pattern of oscillations but not in its qualitative one. However, we need a different method to admit this last hypothesis, because with these traditional methods we cannot observe the true pattern of oscillation in each of these groups of children.

As mentioned before, nonlinear methods has been used to study postural control in children, but have not been used in DCD yet, see Chapter II. For this reason, we tried to apply nonlinear methods ito our research, in tables 21-24 we can find descriptive statistics for them. No significant differences were found for nonlinear data between groups for the same condition and point, see table 20. The variables of DET and laminarity seem not to be adjusted to this kind of data collection, giving values approximate to 100% in all cases. For a more intuitive interpretation, as above, some values are highlighted, the green represents the higher value and the blue represents the lower value.

Considering the data, we can verify for both points that for the same condition between groups, table 21, the p-DCD revealed the lowest value for REC, meanline, entropy and SampEn in all conditions except meanline in SEC and for SampEn in SEC and SD. P-DCD also revealed the lowest maxline in the conditions involving a task DEO and DEC in V. Possibly due to having postural control problems p-DCD children become less recurrent (lowest REC), less periodic (lowest meanline) and also simpler (lowest entropy). At- risk children in V revealed the highest REC, meanline and maxline values except meanline in SEC and maxline in SEO and SEC, and also revealed the highest values of entropy for SEC and SD. For C7 point at- risk revealed the highest values of REC, meanline except in SD and also entropy except in SD. Considering the linear data that appoint at risk children as the ones with more displacement, amplitude and velocity in vertex, the nonlinear demonstrated that these children are also the most recurrent and tendto be the most periodic (meanline). Due to being in a transition zone at- risk children may become more recurrent and periodic to compensate their difficulties.

Therefore, considering the data related to vertex and observing the data inside the same group, table 22, we can verify that p-DCD had the lower values of REC, meanline, maxline and entropy in conditions involving a functional task DEO and DEC. Which is consistent with linear data to the decrease in displacement, amplitude and velocity compared to the baseline conditions SEO and SEC. Surprisingly, for at- risk and typical children the removal of visual information SEO to SEC and DEO to DEC provoked a decrease in values of REC and meanline in both points, and reduced maxline and entropy in V.

P-DCD children that had already revealed in linear data to oscillate less and slower in SEC condition, also revealed in nonlinear data to be more recurrent (higher REC in V and C7) and periodic (higher meanline in V) in the same condition. So as to say, the condition in study with no VI and less external information, compared to the others with the functional task which allowed proprioceptive information about the moulding, was the one to originate less and slower oscillations but also the most recurrent and periodical ones. This could contribute to reinforce that the external information, like VI, is very important to p-DCD children, when external information was removed they restricted and reduced velocity in their oscillations which also became more recurrent and periodic. This increase in recurrence could be one more strategy for these children to compensate their balance problems.

Looking at LyE, and bearing in mind that a positive LyE indicates chaos in the system and the larger the LyE the bigger the instability (Harbourne & Stergiou, 2003), the condition with more stability for p-DCD in both points and at- risk for V was the one with a visual focus, SD, probably the visual anchor of the researcher moulding the ball provided more stability in the children. The less stable condition for all groups in V and C7 (except for at risk in C7) was DEC, which we considered initially to be the most difficult. This highest value of LyE in DEC condition was also accompanied by the smallest meanline values for all groups, in addition, remembering the linear data we also verified and decreased in amplitude and velocity of the oscillations compared to the same condition with eyes open for all children. So, probably the increased difficulty of the condition forced all children to oscillate less and slower, having more instability and being less periodic.

Bearing in mind, that entropy is a measure of predictability or regularity of the system the higher the entropy, the less regular the system is (Pincus & Goldberger, 1994), p-DCD children revealed to be less regular in SEO for V and in SD for C7, and more regular in DEC for both points. This greater regularity in DEC contrasts with the smaller recurrence and periodicity already mentioned. A possible reason for this resided in the fact that entropy only oscillated a few decimals between conditions, we should probably rethink the calculating of entropy namely with a bigger time series.

Curiously for both at- risk and typical children the condition SEO which revealed the smaller and slower oscillations was the one with the higher value of periodicity, higher meanline (except in C7 of typical).

Table 20 - Table 21 – Comparisons for nonlinear data between groups for the same condition and point

Point	Condition	REC		Meanline		Maxline		LyE		DET		Entropy		Sample Entropy		Laminarity		Vmáx	
		H(2)	*p*	*H*(2)	*p*	*H*(2)	*p*	*H*(2)	*p*	*H*(2)	*p*	*H*(2)	*p*	*H*(2)	*P*	*H*(2)	*p*	*H*(2)	*p*
V	**SEO**	1.278	.528	3.142	.208	4.228	.121	1.673	.433	4.507	.105	2.045	.360	2.389	.303	3.701	.157	2.225	.329
	SEC	.142	.931	.501	.778	1.641	.44	.873	.646	4.376	.112	4.805	.09	4.128	.127	1.862	.394	.005	.998
	SD	.507	.776	1.193	.551	1.082	.582	.005	.998	1.278	.528	1.96	.375	.124	.94	1.187	.552	3.054	.217
	DEO	5.902	.052	5.040	.08	3.397	.183	.056	.972	4.05	.132	5.04	.05	1.727	.422	3.701	.157	3.701	.157
	DEC	1.736	.42	2.731	.255	.217	.897	2.591	.274	4.844	.089	3.368	.186	3.104	.212	3.388	.184	1.376	.502
C7	**SEO**	2.16	.34	.954	.621	.954	.621	.948	.623	3.891	.143	1.151	.469	3.433	.180	4.507	.105	.852	.653
	SEC	.05	.975	1.682	.431	1.689	.430	2.160	.34	1.216	.545	1.64	.44	4.521	.104	.547	.761	4.050	.132
	SD	1.216	.545	.547	.761	4.165	.125	.331	.848	1.408	.495	.73	.694	2.179	.336	.22	.896	1.065	.587
	DEO	.351	.839	.136	.934	.079	.961	.24	.887	.36	.835	.273	.873	.691	.708	.360	.835	.044	.978
	DEC	.828	.661	6.816	.033	1.733	.42	3.593	.166	5.902	.052	5.902	.052	6.764	.034	4.844	.089	4.142	.126

Table 22 – Descriptive statistical for nonlinear variables for vertex, values highlighted for highest (green) and lowest (blue) values for the same condition between groups

	REC			Meanline			Maxline			LyE			DET		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	🟦 .22±.002	🟩 .34±.15	.3±.1	🟦 39,7±2,92	🟩 101±63.55	78.98±41.17	🟩 874,5±6.39	865.4±9.0	🟦 854.71±14.09	🟩 9.04±6.07	🟦 4.34±2.21	4.7±4.07	.999±.001	.9998±.0001	.9997±.0003
SEC	.23±.11	.23±.09	.23±.05	🟩 60.96±38.77	🟦 55.59±24.22	58.08±23.82	🟩 868.5±2.12	865±21.66	🟦 853.86±18.15	🟩 5.93±6.38	4.37±3.85	🟦 3.24±3.21	.998±.003	.998±.005	.9997±.0002
SD	🟦 .22±.005	🟩 .27±.11	.24±.04	🟦 53.06±34.47	🟩 53.37±18.52	65.07±25.21	865.5±10.6	🟩 867.7±12.21	🟦 858±15.89	🟦 3.07±3.07	🟩 4.1±4.44	3.67±3.64	.993±.01	.9997±.0002	.9998±.0001
DEO	🟦 .14±.003	🟩 .29±.04	.24±.06	🟦 32.9±11.27	🟩 68.06±23	56.97±11.87	🟦 852±4.24	🟩 866±7.35	864.57±11.93	🟦 5.54±.64	🟩 6.77±3.85	5.55±4.38	.997±.004	.9998±.0002	.9998±.00009
DEC	🟦 .14±0.9	🟩 .24±.13	.17±.05	🟦 27.42±2.37	🟩 49.45±26.58	41.66±6.27	🟦 855±21.21	🟩 863.4±7.77	861.86±10.64	🟩 10.86±4.67	7.18±1.71	🟦 5.77±2.92	.995±.005	.9996±.0004	.9999±.00006

Green – highest value for condition; Blue – lowest value

	Entropy			Sample Entropy			Laminarity			Vmax		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	🟦 4.38±0.94	🟩 4.99±.57	4.75±.54	🟦 .003±.004	🟦 .003±.002	🟩 .008±.009	.999±.001	.9999±.00007	.9999±.0001	🟦 187±45.25	🟩 380.4±184.34	366±178.9
SEC	🟦 4.22±.035	4.4±.22	🟩 4.6±.27	🟦 .002±.00005	🟦 .002±.003	🟩 .007±.007	.999±.002	.999±.003	.9999±.00009	🟩 266.5±212.84	249.2±70.57	🟦 235.86±74.96
SD	🟦 4.27±.79	4.63±.36	🟩 4.78±.3	🟦 .001±.001	🟩 .002±.002	🟩 .002±.004	.996±.006	.9999±.0001	.9999±.00005	🟩 311±70.71	245.8±43.69	🟦 237.14±64.29
DEO	🟦 4.04±.42	🟩 4.83±.24	4.7±.23	🟦 0±.00004	🟦 0±.00004	🟩 .0002±.0003	.998±.003	.999±.00008	.9999±.00005	🟦 171±57.98	🟩 311.4±98.06	272.14±50.79
DEC	🟦 3.81±.22	🟩 4.43±.57	4.34±.2	🟩 .003±.001	.002±.005	🟦 .0016±.001	.997±.003	.9998±.0002	.9999±.00006	🟦 125±83.4	🟩 249.2±149.71	200.86±76.26

Green – highest value for condition; Blue – lowest value

Table 23 – Descriptive statistical for nonlinear variables for vertex, values highlighted for highest (green) and lowest (blue) values for the same group between conditions

	REC			Meanline			Maxline			LyE			DET		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	.22±.002	.34±.15	.3±.1	39,7±2,92	101±63.55	78.98±41.17	874,5±6.39	865.4±9.0	854.71±14.09	9.04±6.07	4.34±2.21	4.7±4.07	.999±.001	.9998±.0001	.9997±.0003
SEC	.23±.11	.23±.09	.23±.05	60.96±38.77	55.59±24.22	58.08±23.82	868.5±2.12	865±21.66	853.86±18.15	5.93±6.38	4.37±3.85	3.24±3.21	.998±.003	.998±.005	.9997±.0002
SD	.22±.005	.27±.11	.24±.04	53.06±34.47	53.37±18.52	65.07±25.21	865.5±10.6	867.7±12.21	858±15.89	3.07±3.07	4.1±4.44	3.67±3.64	.993±.01	.9997±.0002	.9998±.0001
DEO	.14±.003	.29±.04	.24±.06	32.9±11.27	68.06±23	56.97±11.87	852±4.24	866±7.35	864.57±11.93	5.54±.64	6.77±3.85	5.55±4.38	.997±.004	.9998±.0002	.9998±.00009
DEC	.14±0.9	.24±.13	.17±.05	27.42±2.37	49.45±26.58	41.66±6.27	855±21.21	863.4±7.77	861.86±10.64	10.86±4.67	7.18±1.71	5.77±2.92	.995±.005	.9996±.0004	.9999±.00006

Green – highest value for the same group between conditions; Blue – lowest value

	Entropy			Sample Entropy			Laminarity			Vmax		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	4.38±0.94	4.99±.57	4.75±.54	.003±.004	.003±.002	.008±.009	.999±.001	.9999±.00007	.9999±.0001	187±45.25	380.4±184.34	366±178.9
SEC	4.22±.035	4.4±.22	4.6±.27	.002±.00005	.002±.003	.007±.007	.999±.002	.999±.003	.9999±.00009	266.5±212.84	249.2±70.57	235.86±74.96
SD	4.27±.79	4.63±.36	4.78±.3	.001±.001	.002±.002	.002±.004	.996±.006	.9999±.0001	.9999±.00005	311±70.71	245.8±43.69	237.14±64.29
DEO	4.04±.42	4.83±.24	4.7±.23	0±.00004	0±.00004	.0002±.0003	.998±.003	.999±.00008	.9999±.00005	171±57.98	311.4±98.06	272.14±50.79
DEC	3.81±.22	4.43±.57	4.34±.2	.003±.001	.002±.005	.0016±.001	.997±.003	.9998±.0002	.9999±.00006	125±83.4	249.2±149.71	200.86±76.26

Green – highest value for the same group between conditions; Blue – lowest value

Table 24 – Descriptive statistical for nonlinear variables for C7, values highlighted for highest (green) and lowest (blue) values for the same condition between groups

	REC			Meanline			Maxline			LyE			DET		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	🟦 .17±.03	🟩 .31±.23	.24±.06	🟦 33.27±.82	🟩 96.57±91.76	53.9±26.5	858±1414	🟦 854±28.47	🟩 865.57±14.91	🟦 4.59±4.3	5.98±3.3	🟩 7.32±1.94	.996±.004	.9996±.0006	.9992±.001
SEC	.24±1	🟩 .25±.08	🟦 .23±.08	🟦 24.46±20.62	🟩 70.22±48.36	59.5±35.5	🟩 873±21.21	864.4±4.16	🟦 858.43±14.64	🟩 8.55±3.5	🟦 3.5±3.28	5.73±5.11	.965±.05	.9963±.01	.9993±.0006
SD	🟦 .23±.03	🟩 .31±.09	.29±.1	🟩 72.87±31.78	🟦 64.55±22.7	70.43±35.01	🟦 846±21.21	🟩 870±9.82	865.29±9.3	🟦 4.5±.59	🟩 6.64±6.67	4.55±3.94	.997±.005	.9996±.0007	.9996±.0003
DEO	🟦 .21±.01	🟩 .29±.21	🟦 .21±.06	🟦 45.78±33.1	🟩 60.96±10.94	47.25±22.5	🟩 866.5±7.78	865.2±10.94	🟦 864.43±10.71	🟦 5.9±5.9	6.45±7.03	6.76±2.8	.994±.009	.9989±.002	.9995±.0003
DEC	🟦 .13±.09	🟩 .18±.02	.15±.04	🟦 15.4±6.27	🟩 41.95±16.23	29.41±6.82	863.5±12.02	🟦 861.8±5.59	🟩 866.57±6.58	14±.75	🟦 6.48±4.77	🟩 8.81±3.81	.989±.006	.9994±.0005	.9990±.0006

Green – highest value for condition; Blue – lowest value

	Entropy			Sample Entropy			Laminarity			Vmax		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	🟦 4.12±.08	🟩 4.48±0.9	4.4±.6	🟦 .009±.01	.02±.01	🟩 .03±.03	.997±.003	.9999±.00009	.9996±.0005	🟦 205.5±16.26	🟩 343.6±251.21	263.86±17.15
SEC	🟦 3.31±1.46	🟩 4.51±0.5	4.45±.68	🟩 .04±.04	🟦 .006±.01	.03±.03	.977±.03	.998±.01	.9993±.0006	🟦 144±11.31	🟩 327.8±169.97	284.71±76.7
SD	🟦 4.5±.6	4.68±.3	🟩 4.73±.47	.005±.002	🟦 .003±.004	🟩 .012±.02	.998±.003	.9997±.0004	.9998±.0001	🟩 390±171.12	🟦 301.2±144.66	347.7±133.14
DEO	🟦 4.23±.85	🟩 4.45±.63	4.37±.36	🟦 .003±.0009	🟩 .006±.006	🟩 .006±.005	.996±.006	.9996±.0007	.9998±.0001	🟦 223±128.7	🟩 273.6±235.64	231.29±92.92
DEC	🟦 3.2±.41	🟩 4.31±.34	4.02±.29	🟩 .016±.01	🟦 .0033±.003	.01±.009	.993±.005	.9997±.00052	.9996±.0003	🟦 122.5±48.79	🟩 222.2±73.55	151.57±47.78

Green – highest value for condition; Blue – lowest value

Table 25 – Descriptive statistical for nonlinear variables for C7, values highlighted for highest (green) and lowest (blue) values for the same group between conditions

	REC			Meanline			Maxline			LyE			DET		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	.17±.03	.31±.23	.24±.06	33.27±.82	96.57±91.76	53.9±26.5	858±1414	854±28.47	865.57±14.91	4.59±4.3	5.98±3.3	7.32±1.94	.996±.004	.9996±.0006	.9992±.001
SEC	.24±1	.25±.08	.23±.08	24.46±20.62	70.22±48.36	59.5±35.5	873±21.21	864.4±4.16	858.43±14.64	8.55±3.5	3.5±3.28	5.73±5.11	.965±.05	.9963±.01	.9993±.0006
SD	.23±.03	.31±.09	.29±.1	72.87±31.78	64.55±22.7	70.43±35.01	846±21.21	870±9.82	865.29±9.3	4.5±.59	6.64±6.67	4.55±3.94	.997±.005	.9996±.0007	.9996±.0003
DEO	.21±.01	.29±.21	.21±.06	45.78±33.1	60.96±10.94	47.25±22.5	866.5±7.78	865.2±10.94	864.43±10.71	5.9±5.9	6.45±7.03	6.76±2.8	.994±.009	.9989±.002	.9995±.0003
DEC	.13±.09	.18±.02	.15±.04	15.4±6.27	41.95±16.23	29.41±6.82	863.5±12.02	861.8±5.59	866.57±6.58	14±.75	6.48±4.77	8.81±3.81	.989±.006	.9994±.0005	.9990±.0006

Green – highest value for the same group between conditions; Blue – lowest value

	Entropy			Sample Entropy			Laminarity			Vmax		
	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T	p-DCD	R	T
SEO	4.12±.08	4.48±0.9	4.4±.6	.009±.01	.02±.01	.03±.03	.997±.003	.9999±.00009	.9996±.0005	205.5±16.26	343.6±251.21	263.86±17.15
SEC	3.31±1.46	4.51±0.5	4.45±.68	.04±.04	.006±.01	.03±.03	.977±.03	.998±.01	.9993±.0006	144±11.31	327.8±169.97	284.71±76.7
SD	4.5±.6	4.68±.3	4.73±.47	.005±.002	.003±.004	.012±.02	.998±.003	.9997±.0004	.9998±.0001	390±171.12	301.2±144.66	347.7±133.14
DEO	4.23±.85	4.45±.63	4.37±.36	.003±.0009	.006±.006	.006±.005	.996±.006	.9996±.0007	.9998±.0001	223±128.7	273.6±235.64	231.29±92.92
DEC	3.2±.41	4.31±.34	4.02±.29	.016±.01	.0033±.003	.01±.009	.993±.005	.9997±.00052	.9996±.0003	122.5±48.79	222.2±73.55	151.57±47.78

Green – highest value for the same group between conditions; Blue – lowest value

Considering the dynamic systems theory, which defend that each system is a system, we should not focus onlyon the mean values of groups, despite knowing that groups exist, but also concentrate on searching for the individual evolution of the system under the conditions studied. To try to identify patterns in nonlinear measurements tendency tables were performed following the task's order, see tables 25-30. The tables were performed according to the sample groups (p-DCD, at-risk and typical) and points under study (vertex and C7), including the tendencies of all participants inside the same group. The symbol ↑ indicates an increase, $\uparrow_0$ an increase starting at a 0 value, ↓ a decrease, $\downarrow_0$ a decrease to a 0 value, 0 to a 0 value, and → no alteration in data. When all subjects or all except one revealed the same pattern in data for a variable the symbols are painted in dark blue for a quicker visualisation, in the case of typical, in the case where all the subjects except for two revealed the same pattern, the table was painted in light blue.

Table 26 – Tendency table for p-DCD children in vertex point

	Subject	Tasks	REC	Meanline	Maxline	LyE	DET	Entropy	SampEn	Laminiraty	Vmax
p-DCD	1	SEO-SEC	↑	↑	↓	↓	↓	↓	↑$_0$	↓	↑
	2		↓	↓	↓	↑	↓	↓	↓	↑	↓
	1	SEO-SD	↓	↓	↑	↑	↓	↓	↓	↓	↓
	2		↑	↑	↓	↓	↑	↑	↓	↑	↑
	1	SD-DEO	↓	↓	↓	↑	↑	↑	↓	↑	↓
	2		↓	↑	↓	↑	↑	↓	↓	↓	↓
	1	DEO-DEC	↑	↑	↑	↑	↓	↑	↑	↓	↓
	2		↓	↓	↓	↓	↓	↓	↑	↓	↓

Table 27 – Tendency table for at risk children in vertex point

	Subject	Tasks	REC	Meanline	Maxline	LyE	DET	Entropy	SampEn	Laminiraty	Vmax
RISK	3	SEO-SEC	↓	↓	↓	↓	↓	↓	↑	↓	↓
	4		↓	↓	↑	↑	↓	↓	0	↓	↓
	5		↓	↓	↑	↑	↓	↓	$\downarrow_0$	↓	↓
	6		↑	↑	↑	↓	↑	↓	↓	↑	↑
	7		↓	↑	↓	↓	↓	↓	↓	↑	↑
	3	SEO-SD	↑	↑	↑	↑	↑	↑	↓	↓	↑
	4		↑	↑	↑	↓	↑	↑	0	↑	↑
	5		↓	↓	↓	↓	↑	↓	0	↑	↓
	6		↓	↓	↓	↓	↓	↓	↑	↓	↓
	7		↑	↑	↑	↑	↑	↑	↓	↓	↑
	3	SD-DEO	↓	↑	↓	↓	↑	↑	↓	↑	↓
	4		↓	↓	↓	↑	↓	↓	0	↓	↓
	5		↑	↑	↑	↓	↑	↑	0	↑	↑
	6		↑	↑	↑	↑	↓	↑	$\downarrow_0$	↑	↑
	7		↓	↑	↓	↑	↑	↓	↓	↑	↓
	3	DEO-DEC	↓	↓	↓	↑	↓	↓	↑	↓	↓
	4		↑	↑	↓	↓	↑	↑	0	↑	↓
	5		↑	↓	↑	↑	↑	↓	0	↓	↑
	6		↓	↓	↑	↑	↓	↓	$\uparrow_0$	↓	↓
	7		↓	↓	↑	↓	↓	↓	$\downarrow_0$	↓	↑

Table 28– Tendency table for typical children in vertex point

	Subject	Tasks	REC	Meanline	Maxline	LyE	DET	Entropy	SampEn	Laminiraty	Vmax
TYPICAL	8	SEO-SEC	↓	↓	↑	↑	↓	↑	↑	↑	↓
	9		↑	↑	↑	↓	↑	↑	↓	↑	↓
	10		↓	↓	↓	↓	↓	↓	↓	↓	↓
	11		↓	↓	↑	↓	↑	↓	↓	↓	↑
	12		↓	↓	↑	↓	↓	↓	↑	↓	↓
	13		↓	↓	↑	↓	↓	↓	$\uparrow_0$	↓	↓
	14		↑	↓	↓	↓	↓	↓	↑	↓	↑
	8	SEO-SD	↑	↑	↓	↓	↑	↑	↑	↑	↑
	9		↓	↓	↓	↑	↓	↓	↓	↓	↑
	10		↑	↑	↑	$\downarrow_-$	↑	↑	$\downarrow_0$	↑	↓
	11		↑	↑	↓	↑	↑	↑	↓	↑	↑
	12		↑	↑	↑	↓	↑	↑	↓	↑	↑
	13		↓	↑	↓	↓	↑	↑	↑	↑	↓
	14		↓	↓	↑	↑	↑	↓	↓	↑	↓
	8	SD-DEO	↓	↓	↑	↑	↑	↓	$\downarrow_0$	↑	↓
	9		↑	↑	↓	↓	↑	↓	$\downarrow_0$	↑	↑
	10		↑	↓	↑	$\uparrow_-$	↓	↓	$\uparrow_0$	↓	↑
	11		↓	↓	↓	↓	↓	↓	$\downarrow_0$	↓	↑
	12		↓	↓	↓	↓	↓	↓	↓	↓	↓
	13		↓	↓	↓	↓	↓	↓	↓	↓	↓
	14		↓	↑	↓	↓	↑	↑	$\downarrow_0$	↑	↑
	8	DEO-DEC	↓	↓	↑	↑	↓	↓	$\uparrow_0$	↓	↓
	9		↓	↓	↓	↑	↓	↓	↑	↑	↑
	10		↓	↓	↑	↑	↓	↓	$\uparrow_0$	↓	↓
	11		↑	↓	↑	↑	↓	↓	$\uparrow_0$	↑	↓
	12		↓	↓	→	↑	↓	↓	↑	↓	↓
	13		↓	↓	↓	↓	↓	↓	↑	↑	↓
	14		↓	↓	↓	↓	↓	↓	$\uparrow_0$	↓	↑

Table 29– Tendency table for p-DCD children in C7 point

	Subject	Tasks	REC	Meanline	Maxline	LyE	DET	Entropy	SampEn	Laminiraty	Vmax
p-DCD	1	SEO-SEC	↑	↓	↑	↑	↓	↓	↑	↓	↓
	2		↑	↑	↑	↓	↑	↑	↓	↑	↓
	1	SEO-SD	↓	↑	↓	↓	↑	↑	↓	↑	↑
	2		↑	↑	↓	↓	↑	↑	↓	↑	↑
	1	SD-DEO	↓	↓	↑	↑	↓	↓	↓	↓	↓
	2		↓	↓	↓	↓	↓	↓	↑	↑	↓
	1	DEO-DEC	↓	↓	→	↑	↓	↓	↑	↓	↑
	2		↓	↓	↓	↑	↓	↓	↑	↓	↓

Table 30 – Tendency table for at risk children in C7 point

	Subject	Tasks	REC	Meanline	Maxline	LyE	DET	Entropy	SampEn	Laminiraty	Vmax
RISK	3	SEO-SEC	↑	↑	↑	↓	↑	↑	↓	↓	↑
	4		↓	↓	→	↑	↓	↓	$\downarrow_0$	↓	↓
	5		↓	↓	↑	↑	↓	↓	$\downarrow_0$	↓	↓
	6		↓	↑	↓	↓	↑	↑	↓	↑	↑
	7		↑	↑	↑	↓	↑	↑	↓	↑	↑
	3	SEO-SD	↑	↑	↑	↑	↓	↑	↓	↑	→
	4		↑	↓	↓	↓	↑	↑	0	↑	↑
	5		↑	↓	↑	↑	↑	↓	0	↑	↑
	6		↓	↓	↓	↑	↓	↓	↓	↓	↓
	7		↑	↑	↑	↓	↑	↑	↓	↑	↓
	3	SD-DEO	↓	↓	→	↑	↓	↓	↓	↓	↓
	4		↓	↓	↑	↑	↓	↓	$\uparrow_0$	↓	↓
	5		↑	↑	↓	↓	↓	↑	0	↑	↓
	6		↑	↓	→	$\downarrow_-$	↑	↑	$\uparrow_0$	↑	↑
	7		↓	↓	↓	↓	↓	↓	↑	↓	↓
	3	DEO-DEC	↑	↑	↓	↓	↑	↑	↓	↑	↑
	4		↓	↑	↓	↓	↑	↑	↓	↑	↑
	5		↓	↓	↓	↓	↓	↓	↓	↓	↑
	6		↓	↑	↓	$\downarrow_-$	↑	↑	↓	↑	↑
	7		↑	↑	↑	↑	↑	↑	↓	↓	↑

Table 31– Tendency table for typical children in C7 point

	Subject	Tasks	REC	Meanline	Maxline	LyE	DET	Entropy	SampEn	Laminiraty	Vmax
TYPICAL	8	SEO-SEC	↑	↑	→	↓	↑	↑	↓	↑	↑
	9		↑	↑	↓	↓-	↑	↑	↓	↑	↑
	10		↓	↓	↓	↓	↑	↑	↓	↑	↓
	11		↓	↓	↓	↑	↓	↓	↓	↓	↑
	12		↓	↓	↓	↑	↓	↓	↑	↓	↓
	13		↓	↓	↑	↓	↓	↑	↑	↓	↓
	14		↓	↓	↑	↑	↓	↓	↑	↓	↓
	8	SEO-SD	↑	↑	↓	↓	↓	↑	↓0	↑	↑
	9		↓	↓	↑	↑-	↓	↓	↑	↓	↓
	10		↑	↑	↑	↓-	↑	↑	↓	↑	↑
	11		↑	↑	↑	↑	↑	↑	↓	↑	↓
	12		↑	↑	↓	↓	↑	↑	↓	↑	↑
	13		↑	↓	↑	↑	↓	↓	↑	↓	↑
	14		↓	↓	↓	↓	↑	↑	↓	↑	↓
	8	SD-DEO	↓	↓	↓	↓	↓	↓	↑0	↓	↓
	9		↓	↓	↓	↓	↓	↓	↓	↓	↓
	10		↓	↓	↑	↑-	↓	↓	↑	↓	↓
	11		↓	↓	↓	↓	↓	↓	↓	↓	↓
	12		↓	↓	↓	↓	↓	↓	↑	↓	↓
	13		↓	↓	↓	↑	↑	↑	↓	↑	↓
	14		↓	↓	↓	↑	↑	↓	↑	↓	↓
	8	DEO-DEC	↑	↓	↑	↓	↑	↓	↑	↓	↑
	9		↓	↓	↓	↑	↓	↓	↑	↓	↓
	10		↓	↓	↓	↑	↓	↓	↑	↓	↓
	11		↓	↓	↑	↑	↓	↓	↑	↑	↓
	12		↓	↓	→	↓	↓	↓	↓	↓	↓
	13		↓	↓	↓	↓	↓	↓	↑	↓	↓
	14		↓	↓	↓	↑	↓	↓	↓	↑	↓

The efforts in designing the tendency tables with nonlinear measurements revealed some behaviour patterns, however, it would be important in future studies to increase the sample in order to identifythese patterns more easily and accurately. . The most remarkable patterns are present in the retrieval of visual information during the functional task, DEO to DEC, the p-DCD children revealed a decrease in both points in determinism (DET), intermittency (laminarity) and an increase of regularity (SampEn), it was also noted a decrease in C7 point of recurrence (REC), stability (meanline) and also higher entropy (higher LyE). These changes seem to evidence the added difficulty of the task. Also, at risk children reduced the periodicity (meanline) in V and the stability (maxline) in C7. Typical children revealed for both points a decrease in recurrence, determinism, periodicity, complexity (entropy) and but also an increase in regularity (higher SampEn). The variables of REC, maxline and entropy seem to be more sensitive to the conditions under study.

The present research aims to explore an area that was still unexplored by also applying nonlinear methods in the analysis of postural control in p-DCD children, see chapter II. However, and being the first in this specific area, we encountered a few problems in the nonlinear data application. We believe that the nonlinear measurements did not reveal more behaviour patterns not that it was not suitable for children with motor disorders, which was already proved in CP (e.g. Deffeyes, Harbourne, DeJong, et al., 2009; Deffeyes, Harbourne, Kyvelidou, et al., 2009; Kyvelidou et al., 2013), but for the data collection. Previous studies that used nonlinearity in postural control with children, used force platforms to collect the data. Unfortunately, we did not have that option and only collected data through video recording, analysing it afterwards with APAS. Having reduced the all-time series to a common denominator (Yentes et al., 2013) and applying the power spectrum that is an essential part if the data treatment (Deffeyes, Harbourne, Kyvelidou, et al., 2009), and despite collecting the initial data at a high speed (240Hz) we were left with a time series of 900 data each. This is a larger number than 200, the minimum to calculate SampEn (Yentes et al., 2013), but still far from the 2000 data used by other authors who calculated nonlinear measurements in this kind of study (Deffeyes, Harbourne, Kyvelidou, et al., 2009; Kyvelidou et al., 2013).

This way we believe that it is possible to use nonlinear methods in analysing postural control with DCD children, however it is crucial to find a more suitable strategy for the data collection in order to obtain the biggest time series possible.

Although the data limitations in nonlinear treatment already mentioned, the limitations of the present study reside mainly in the sample, which is not representative of the universe for not being random and also becuse of its reduced size.

4. Conclusions

The dynamical error of APAS application in the study was measured through the calculation of average error and ICC values. In general, the average error was reduced, andthe ICC calculation revealed a reliable data with 1 moderate, 1 good and 4 excellent values. The transverse plan was the less reliable while frontal and sagittal planes revealed excellent ICC values.

For all children groups, it was noted postural control alterations between conditions, however, no significant differences were found probably due to the small sample size. The linear treatment revealed some interesting data and continue to prove their value in postural control analyses.

P-DCD children oscillated more (in total and in amplitude) and faster in condition with visual information (SEO and DEO) for V and C7, contrasting to at -risk and typical children who oscillated less and slower in SEO. Past studys also revelaed that even CP children oscilate more in AP direction than typical during sitting position with eyes open (Kyvelidou et al., 2013).

With a visual focus p-DCD children oscillated less (in total) and more slowly compared to the baseline condition for both points. Maybe, the focus on researcher manipulation worked as a visual anchor which in some way altered their postural control.

When removing visual information, p-DCD children reduced their oscilations and velocity for both points. Possibly they freeze more degrees of freedom in order to respond to absence of external information. The visual information seems to be an important part of p-DCD postural control, the greater the complexity of the task, the fewer and slower the oscillations were. Despite supposedly DEC being more difficult than SEC for involving the moulding and the blindfolded eyes simultaneously, SEC revelaed the smallest and slowest oscillations that we expected for the hardest task. Probably p-DCD are more dependent on external stimulus to auto organize their own balance, comparing DEC to SEC, in DEC they had more external information with proprioceptive informationon the moulding of the ball. Maybe the simple fact of performing a functional task can help them to manage their posture. To be honest, we should rethink our intervention on these children and focus on functional tasks.

For the two points in study, C7 and vertex, at -risk children were the ones to oscillate more and faster in all conditions except in SEO condition. It is possible that due to being in a transition zone these children were searching for motor solutions and oscillated more and faster than the others. Despite this, at- risk children revealed a behaviour pattern similar to typical in both points. For the two groups in the simpler conditions, SEO e SEC, children oscillated less and more slowly, and for the hardest conditions that envolve a functional task, DEO e DEC, they oscillated more and faster.

All children groups revealed the same mode of action when visual information was removed during a functional task, with less and slower oscillations; in this case, DCD children have the same qualitative postural mechanism as typical. It is likely that the problem p-DCD children have, is not in modes of motor control, butin perception-action cycles' effectivness (Chen et al., 2014); where stimulation must be focused.

The control of the head and trunk was coordinated, in the sense of intersegmental coordination, independently of the pattern of motor development, which has an observable effect in the quantitative pattern of oscillations but not in its qualitative one. It is interesting to note that for all groups, on all points and in all conditions the head, V, always oscillated more and faster than the trunk, C7.

With regard to nonlinear data the variables of DET and laminarity seem not to be adjusted to this kind of data collection giving values close to 100% in all cases, it is necessary to rethink the data collection in future studies.

P-DCD children group revealed, for all groups and in both points, the lowest value for REC, meanline, entropy and SampEn in all conditions (except meanline in SEC and SampEn in SEC and SD), and also the lowest maxline in the conditions involving a task for V. Due to having postural control problems p-DCD children become less recurrent (lowest REC), less periodic (lowest meanline) and also simpler and more regular (lowest entropy and highest SampEn).

Between conditions, p-DCD exhibited the lower values of REC, meanline, maxline and entropy in conditions involving a functional task DEO and DEC. Which is consistent with linear data that revealed a decrease in displacement, amplitude and velocity in DEO and DEC comparing with the baseline conditions SEO and SEC, which we associated to a freeze of freedom degrees in order to overcome the increased difficulty.

P-DCD children that had already revealed in linear data to oscillate less and slower in SEC condition, also revealed in nonlinear data to be more recurrent (higher REC in V and C7) and periodic (higher meanline in V) in the same condition. Similarly, the condition in study with no VI and less external information was the one to originate less and slower oscillations but also the most recurrent and periodical ones. This could contribute to reinforce the idea that the external information is very important to p-DCD children, when removed they restricted and reduced velocity in their oscillations which also became more recurrent and periodic. This increase in recurrence and periodicity could be one more strategy for these children to compensate their balance problems.

In general, the nonlinear demonstrated that at- risk children were the most recurrent (REC) with a tendency to be the most periodic (meanline). Also, linear data revealed these children as the ones with more displacement, amplitude and velocity for all condition except SEO. Maybe for being in a transition zone at risk children oscillate more and faster searching for a motor solution but also in a more recurrent and periodic manner to compensate their difficulties.

Looking at LyE, the condition with more stability for p-DCD in both points and at risk for V was the one with a visual focus, SD, probably due the visual anchor of the researcher moulding the ball. The less stable and periodical condition for all groups in both points (except for at risk in C7) was DEC, also in linear data this condition provoked a decrease in amplitude and velocity of the oscillations for all children. So, probably the increased difficulty of the condition forced to all children to oscillate less and slower, having more instability and being less periodic.

We believe that is possible to use nonlinear methods in analysing postural control with DCD children, however, it is crucial to find a more suitable strategy for data collection in order to obtain bigger time series of at least 2000 data study (Deffeyes, Harbourne, Kyvelidou, et al., 2009; Kyvelidou et al., 2013).

The limitations of the present study reside mainly in the small-time series, which was mentioned and explained above, and in the sample, which was small and of convenience. In future studies, the ideal condition would be to use a random, big, representative sample, with investigators applying the battery blind to study trial.

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Chapter V

General Discussion and Conclusions, Recommendations

1. General Discussion and Conclusions

The present dissertation revealed strong points and some limitations which deserve our attention in order to deepen in the study of postural control and also improve in future studies.

The strong points resided in the pertinence and innovation of the dissertation. The DCD is a motor disorder identified and recognized by DSM. The inexistence of intellectual, neural and other severe health complications makes it a possible filed of intervention by sports graduates. That being said, it makes sense to choose this as the theme of a Master Dissertation in Physical Activity in Special Populations. The "DCD theme" is and always will be a pertinent theme to study more deeply due to the fact that this is one of the major health problems among school-aged children worldwide (Caçola, 2016). Inside the DCD, and bearing in mind that it is a very heterogeneous disorder, the present dissertation approached the postural control due to its prevalence and importance in the daily life of children, including their sport life.

The innovation resided in two main aspects, first the incorporation of at- risk children in the study, being that normally the literature only approaches the extremes considering children with disorder and typical, leaving this "grey zone" unstudied. And secondly, the application of nonlinear methods in the analysis of postural control in DCD. These methods have proven to be a valuable and reliable methodology in other motor disorders like CP, but had not yet been used in DCD, as we can confirm in a systematic review in 5 databases and in 4 languages mentioned in chapter II. Still, in the innovation field it is interesting to note that the present dissertation despite being written by a Portuguese master student, whohas no need to write this in English, preferred to write it in the universal languageto fulfil what should be one of the most important concerns of investigators, to increase the opportunity to disseminate knowledge.

All of the dissertation's goals were fulfilled. As defined initially, a systematic review was performed to identify all the methodologies already used in the study of postural control with DCD children. This review not only provided the opportunity to analyse and synthetize pertinent information regarding this theme, but also to identify some clues for a better and more suitable methodologic choice for the balance study. It was carefully conducted in order to maximize the search spectrum, 5 electronic databases were used: Pubmed, Science Direct, Scopus, Web of Science, Cochrane and Scielo. Which were selected due to representing a wide spectrum of disciplines that perform research in DCD (e. g. Adams, Lust, Wilson, & Steenbergen, 2014). Taking into account that different terminology is used to refer to postural control, a combined search has been applied using the equivalent terms; an equivalent term, the acronym and the complete designation for DCD was also used. Moreover, to maximize the spectrum of the search even more this was performed in 4 languages: English, French, Portuguese and Spanish. Despite our effort and concern in maximizing the search noarticle approaching postural control in DCD children using nonlinear methods was found. Only linear methods were identified through 9 eligible articles which used wide and varied methodological approaches like COP analysis, limit of stability tests, equilibrium scores, electromyography, accelerometer and dynamometry all using biomechanical instruments.

In general, DCD children appear to be more dependent on visual information (Deconinck et al., 2006; Fong et al., 2012; Tsai et al., 2008), and to be more variable and oscillate more in a standing condition especially when the task becomes more difficult (Chen et al., 2011; Chen et al., 2012; Przysucha & Taylor, 2004; Tsai et al., 2008; Tsai et al., 2009). According to the studies analysed in the review it was possible to identify some clues for a more suitable intervention with DCD children: take into account attentional factors (Chen et al., 2012; Tsai et al., 2009); work on the perception-action link (Chen et al., 2011; Fong et al., 2012) bearing in mind that the child is a dynamic system which is influenced by the environment, and needs the information of this one in order to maintain its posture and/or complete a task; work on the timing of gastrocnemius contraction that is late compared to TD, and also improve this peak force (Fong et al., 2015); increase the limit of stability in backward excursion which is significantly less (Fong, Guo, et al., 2016).

As mentioned initially it was applied the MABC-2 (Henderson & Sugden, 2007) (see chapter III), the battery was applied to 46 children (3.9±0.26 years old, 25 girls and 21 boys) of 3 different preschools and allowed to identify 2 probable DCD children (4.4%), 7 at risk zone (15.2%) and 37 with a typical motor development (80.4%).

In the present study the percentage of probable DCD, was slightly lower, 4.4%, than the 5-6% referred in literature probably due to the sample size (Vaivre-Douret, 2014; Vaivre-Douret et al., 2011). The proportion between dexterous and left-handed found was also closer to what is referred in literature, 90% and 10% respectively (Fonseca, 2011; Perelle & Ehrman, 2005), with values of 89.1% and 10.9%. In the at-risk group all children were dexterous, and in the DCD group all children were left-handed. Similarly to Cairney et al. (2008) study, a higher prevalence of probable DCD in boys was not detected.

One of the numbers revealed in this investigation that should concern and deserve our undivided attention is the prevalence of at- risk children, this was 15.2%, about the triple (3.4 times higher) than DCD prevalence. Despite not having the disorder, these children display motor impairments that can improve with a suitable intervention or, otherwise, get worse if we simply let pastime takes its place. This possibility given by MABC-2 of identifying at- risk children should be more deeply explored as these also deserve to be helped in their motor development, according to the present study for 1 DCD children we will find 3 to 4 at risk.

Exploring the MABC-2 scores the children with typical development revealed a mean percentile score of 69±24 well above percentile 16, which separates typical motor development from at- risk. While the group at risk presented a mean value near to the limit of a typical motor development with a percentile score of 15±2.6, as previously determined in a study (Arrais, 2014) with a larger sample from the same geographical area.

A deeper analysis of MABC-2 scores allows researchers to identify cases where children with a total score of typical revealed classification of at- risk or DCD in some categories. It was found that 1 typical child with at -risk classification in manual dexterity, 5 in aiming-catching, 4 in balance, and 1 with DCD classification in aiming-catching. Additionally, among the children with a total score of at- risk and probable DCD it is possible to find categories with different classifications, the total score does not have to be equal to all categories of classifications. This possibility discriminates categories and classifies them, especially bearing in mind that DCD children are a very heterogeneous group (Vaivre-Douret et al., 2011b), it may not only be a diagnostic tool, but also an intervention tool that allows the professionals to individualize and specify the intervention on the children that they have before them.

Looking at the categories scores, it was interesting to note that the least scored were aiming-catching for typical development and probable DCD children, and balance for at risk children. Probably due to fewer practice of activities requiring aiming-catching and balance contrasting with a bigger incidence in manual dexterity activities, in order to prepare children for primary school. It is very common in the Portuguese kindergartens to involve children in tasks like drawing, drawing lines or painting within limits in order to increase their manual dexterity and in this manner prepare them for primary school.

Beyond the academic data or results, the MABC-2 application provided results that despite not being accounted for they were equally important. In the preschools were the study occurred, the educators and parents become more aware and more informed about DCD. It is important to note, that inspite of the growing interest of academic community in DCD this disorder, it is often undiagnosed, and a possible reason for that is simply lack knowledge of DCD. In Portugal, the awareness of educators or parents of DCD had not yet been investigated, however, in a survey including the United States of America, Canada and United Kingdom, only 41% of the paediatricians knew DCD and even fewer knew about the consequences, only 23% of teachers and 6% of parents knew about the disorder (Wilson et al., 2013). So, in Portugal, a country that is now taking its first steps in these disorders, we suppose that the numbers could be even smaller. For this reason, it is important to recognize not only the direct results, but also the indirect results and benefits of the present study, like the dissemination of the information and more awareness to DCD.

Another positive and important point of the study consisted of the information given to parents about the MABC-2 application, all parents that allowed their children to participate in the study received in theend a personal report with the scores of their child and also, if needed, indications and suggestions for a home intervention. This way, the parents got to learn if their child had or not a typical motor development and, if not, the parent has now a deeper knowledge of the disorder and about their own son that can help them to make the best decisions on their child’s behalf. For example, follow the motor suggestion given by the investigator or incorporating the child in motor activities or suitable therapy.

This personal report to parents worked as a bridge between academy and parents, leaving them the information and some tools to improve the quality of life of their children. Only by working together can we continue to study and improve therapy for DCD children and for all disorders.

After meeting the goals described above, which contributed with pertinent information for methodological choices and with the sample identification, the main purpose was fulfilled, the study of postural control. This provided some interesting linear and nonlinear data but also revealed some problems in the application of nonlinear techniques, which were the limitations of the present dissertation.

The data were collected through filming and then was analysed with APAS to access the time series. The APAS dynamic error were analysed calculating the average error and ICC values for both points in study, C and C7, and for all three plans, frontal transverse and sagittal. In general, the average error was reduced, the biggest value found was 3.12 mm for C7 point in transverse plan, and the smaller was 0.4 mm for C7 point in sagittal plan. The ICC calculation, a statistic technique which measures the values reliability of two or more measures (Koo & Li, 2016), revealed a reliable data with 1 moderate, 1 good and 4 excellent values. The transverse plan was the less reliable with moderate and good values, 0.679 and 0.836 respectively, while frontal and sagittal planes revealed excellent values between 0.914 and 1.

For all children groups, it was noted postural control alterations between conditions.

P-DCD children oscillated more and faster for both points in the conditions with VI, sitting eyes open (SEO) and doing eyes open (DEO), contrasting to at- risk and typical children where despite oscillating more and faster in DEO they oscillated less and more slowly in SEO. Previous studies also revealed that CP children oscilated more in AP direction than typical one during sitting position with eyes open (Kyvelidou et al., 2013).

Compared to the baseline condition, SEO, p-DCD oscillated less and more slowly for both points when a visual focus of attention was introduced. Maybe, the focus on researcher manipulation worked as a visual anchor that in some way altered their postural control.

These reductions in the oscillations and velocity are even more visible when the VI was retrieved. Moving from the condition of sittng eyes open (SEO) to sitting eyes closed (SEC) p-DCD children decreased their oscillations and velocity while at- risk and typical increased. Also moving from doing eyes open (DEO) to doing eyes closed (DEC), p-DCD children continued to decrease their oscilations and velocity, even notecing that all groups who reduced these variables p-DCD are the ones that revealled lowest values. It could be, that these reductions reflect a freeze of freedom degrees in order to respond to absence of external information. The greater the complexity of the task, the lesser and slower the oscillations were. To reinforce that we can verify that p-DCD group is the one with lowest oscillations and velocity during the tasks involving a functional task, DEO and DEC, the increase in task difficulty could lead once again to fewer and slower oscillations.

Taking into account, that the greater the complexity the fewer and slower the oscilations, it could be strange to see that sitting eyes closed (SEC) results in a lower value for all varaibles than doing eyes closed (blindfolded) (DEC). Supposely, DEC for envolving simultaneously the eyes closed, no VI, and a functional task should be the hardest task, so, should it be the one with the lowest values of oscillations and velocity. Looking at data in a holistic way we can also see that p-DCD children are the ones that revealed the lowest values for conditions with no VI, we can suppose that these children foccus and depend moreon external stimulus like VI than the other groups. In this way, being more depend on external information. The condition of DEC can give them more information, namely proprioceptive information about the moulding of the ball, than SEC condition. Being true that p-DCD children are more dependent form external information to auto organizae their own balance, a simple task could help them to manage their postural balance. It is time to think about it and to reconsider the intervention with these children.

At- risk children revelead the highest TD-AP, A-AP and MV-AP, in all conditions and in both points, except in the baseline sitting eyes open (SEO). Maybe, for being in a transition zone where they did not have the disorder but had motor impairments,leaving at- risk children to try to explore solutions that resulted in more and faster body oscillations (in total and amplitude). Despiste being the group that oscillated more and faster in all conditions, we could verify the H1, at- risk children revealed a pattern of behaviour similar to typical. For the two groups and in both points in the simpler conditions, SEO e SEC, they oscillated less and more slowly, and for more difficult conditions that envolved a task, DEO e DEC, they oscillated more and faster.

All children groups had the same mode of action when the visual information was removed during a functional task, children oscillated less and more slowly compared to the same condition with eyes open. So, generally speaking, p-DCD, at- risk and typical have the same qualitative postural mechanisms in this case as typical children, although with different quantitative outputs. To be true, it may mean that the problem of DCD children is not in forms of motor control, but on perception-action cycles' effectivness (F. C. Chen et al., 2014); and, where stimulation must be focused.

Relatively to head and trunk it seems that they were coordinated, in the sense of intersegmental coordination, independently of the pattern of motor development. It is interesting to note, that for all groups, on all points and in all conditions the head, V, always oscillated more and faster than the trunk, C7.

Looking at nonlinear data we can verify that some variables seem not to be adjusted, DET and laminarity had values close to 100% in all cases, and SampEn presented very low values near 0. These situations did not mean that nonlinear methods are not suitable to study PC in DCD children, being that they had already proved their value in the analysis of PC in other motor disorders like cerebral palsy (e.g. Kyvelidou et al., 2010). We believe that the reason for this is related to data collection, despite collecting the initial data at a high speed (240Hz) for 30 seconds, which should represent 7200 data. The need to reduce time -series to a common denominator (Yentes et al., 2013) and apply the power spectrum, which is an essential part if the data treatment (Deffeyes, Harbourne, Kyvelidou, et al., 2009), makes us arrived at a final time series of 900 data. This is a larger number than 200, the minimumto calculate SampEn (Yentes et al., 2013), but is far from the 2000 data used by other authors who calculated nonlinear measurements in this kind of study (Deffeyes, Harbourne, Kyvelidou, et al., 2009; Kyvelidou et al., 2013).

In this way the principal limitation of the present dissertation was the size of time series that conditioned the calculating of some nonlinear data. Even so, we found some interesting nonlinear data and patterns.

P-DCD children revealed for both points in study, V and C7 ,to be the group with lowest value for REC, meanline, entropy and SampEn in all conditions except meanline in SEC and for SampEn in SEC and SD. P-DCD also revealed the lowest maxline in the conditions involving a task DEO and DEC in V. Maybe for having postural control problems p-DCD children become less recurrent (lowest REC), less periodic (lowest meanline) and also simpler (lowest entropy).

During the conditions involving a functional task p-DCD had the lower values of REC, meanline, maxline and entropy. Which is consistent with linear data that revealed a decrease in displacement, amplitude and velocity in DEO and DEC compared to the baseline conditions SEO and SEC. The removal of VI provoked and decrease in all groups in the values of REC and meanline in both points, and reduced maxline and entropy in V. This highlights the importance of visual information, and reinforces that p-DCD mayhave had the same qualitative postural mechanisms than typical, and presented a problem not in the mode of PC but on perception-action cycles' effectivness (Chen et al., 2014) as mentioned above.

At- risk children revealed in V point the highest REC, meanline and maxline values except meanline in SEC and maxline in SEO and SEC, and also revealed the highest values of entropy for SEC and SD. For C7 point at risk revealed the highest values of REC, meanline except in SD and also entropy except in SD. Also considering the linear data at- risk children were the ones who tended to feature more displacement, amplitude and velocity. Maybe for being in a transition zone at- risk children oscillated more and faster searching for motor solutions but at the same time oscillated in a more recurrent and periodic manner to compensate their difficulties.

Looking at LyE, and bearing in mind that the larger the LyE the bigger the instability (Harbourne & Stergiou, 2003), themost stable condition for p-DCD in both points and at- risk for V was the one with a visual focus, SD, probably the visual anchor provided more stability to the system. The less stable condition for all groups in V and C7 (except for at risk in C7) was DEC, which we considered initially to be the most difficult. This highest value of LyE in DEC condition was also accompanied by the smallest meanline values, periodicity, for all groups. Already in linear data we verified a decrease in amplitude and velocity compared to the same condition with eyes open for all children. So, probably the increased difficulty of the condition forced all children to oscillate less and slower, having more instability and being less periodic.

We believe thatit is possible to use nonlinear methods in analysing postural control with DCD children namely the LyE and REC, however it is crucial to find a more suitable strategy for data collection in order to obtain biggertime series of at least 2000 data study (Deffeyes, Harbourne, Kyvelidou, et al., 2009; Kyvelidou et al., 2013). More investigation in this field with nonlinear methods is needed, the present dissertation could and will be a future point for more investigation and hopefully even better.

Considering the hypothesis elaborated in chapter it was verified H1, children at risk despite having a high quantitative liner data revealing a similar behaviour to typical children.

The H2 that appointed to p-DCD be more regular, periodic and complex than typical and at risk was not verified, contrary to what was expected DCD children revealed a tendency to be less recurrent, less periodic and also simpler than other children.

The H3 that appointed to a more regular behaviour in p-DCD with the introduction of a visual focus cannot be verified due to problems inherent to the SampEn application (higher SampEn less regularity). However,it is interesting to note, that compared to the baseline condition, SEO, p-DCD oscillated less and more slowly for both points when a visual focus of attention was introduced. This was also the most stable condition for p-DCD with the lowest LyE value. Maybe, the focus on researcher manipulation worked as a visual anchor that in some way altered and stablish their postural control.

The H4 appointed that p-DCD reveal a more regular and complex behaviour during the conditions with a functional task than without tasks or visual focus, we could not confirm this hypothesis. Despite it in conditions with a functional task p-DCD reduced their oscillations and velocity. Moving from the condition of SEO to SEC p-DCD children decrease their oscillations and velocity while at risk and typical increased. Also moving from DEO to DEC, p-DCD children go back to to decreasing their oscilations and velocity, even notecing that all groups that reduced these variables p-DCD are the ones that revealled lowest values. Maybe these reductions reflect a freeze of freedom degrees in order to respond to absence of external information. The greater the complexity of the task, the lesser and slower the oscillations were.

The H5 supposed that during the functional task the removal of vision, SEC, would lead p-DCD to a less regular behaviour. We could not measure the regularity correctly, but this was the less stable condition for all children groups with the highest values of LyE and smallest meanline values which represent less periodicity.

As mentioned before and looking in a holistic way at this dissertation the principal limitation resided in the size of the time series and, consequently, the difficulties in the application of some nonlinear variables. The other limitation consistedof using a small convenience sample in preschools, so at start of the study we did not consider the children that are not included in preschools. Therefore, the sample is not representative of the universe for not being random and also due to its reduced size. The investigator that applied MABC-2 battery test was not blind to the study purpose, so it is a threat to the internal validity of the study. In future studies, the ideal condition would be to use a random, big and representative sample, with investigators applying the battery blind to the study purpose, so we can make conclusions for all the sample's universe and eliminate internal threats.

In a more personal balance, the present dissertation provided several and difficult challenges to the master student and author, but thinking back on the dynamic system theory it is necessary to introduce some instability to the system so that it evolves to the next level, to the next attractor. We really hope that this dissertation could lead us to the next level and result in future and even better studies. Despite being a constant challenge namely by writing in English and also for being the first study using nonlinear methods, and several at the same time, in PC study with p-DCD, in the end, it was worth it.

Who sad that instability could not be a good thing?

Everything is worth it if the soul is not small…
Fernando Pessoa

2. Recommendations

For future studies it would be interesting to increase the sample of MABC-2 application to obtain a large number of p-DCD and at-risk children. In the case of a big sample it would also be interesting to divide p-DCD and at- risk children into balance problems and no balance problems.

According to the present systematic research, and despite having already been successfully used in other motor disorder like CP (Deffeyes et al., 2011), nonlinear methods have not yet been applied in studies of postural control in DCD. Our suggestion consists of all linear and nonlinear methods undergoing if possible a methods' triangulation.

To apply nonlinear methods in postural control study, the investigators must seriously ponder the methods of data collection. It would be interesting to perform a case study first, so as to analyse for those conditions and data collection type, if after the power spectrum was applied all that means of collecting data allows them to retrieve a big-time series. The present dissertation seemed to prove that a larger time series is necessary to apply the nonlinear routines, perhaps at least 2000 data (Deffeyes, Harbourne, Kyvelidou, et al., 2009).

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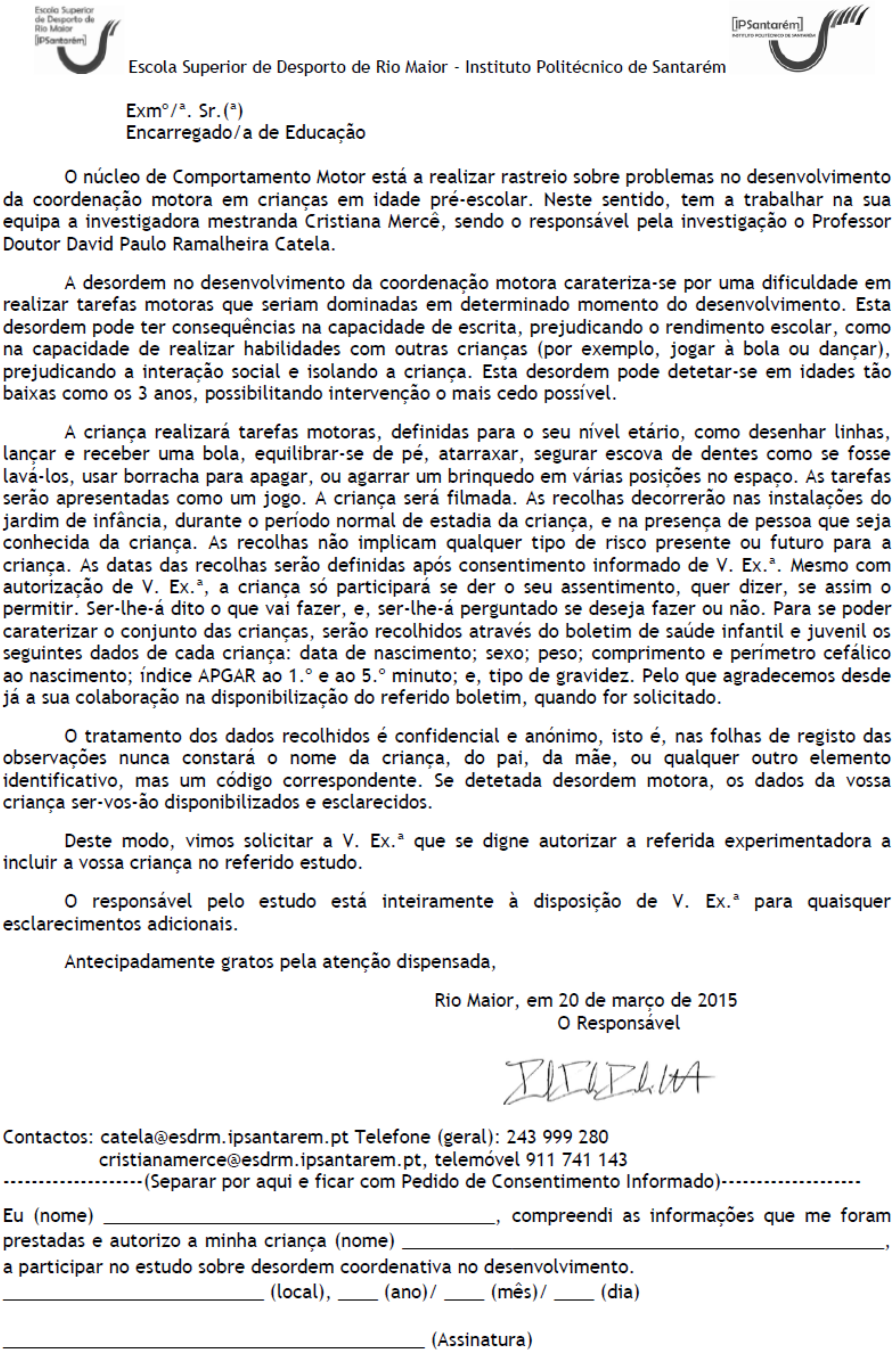
Appendixes

Appendix 1 – Informed consent to parents



Escola Superior de Desporto de Rio Maior - Instituto Politécnico de Santarém

Exmº/ª. Sr.(ª)
Encarregado/a de Educação

O núcleo de Comportamento Motor está a realizar rastreio sobre problemas no desenvolvimento da coordenação motora em crianças em idade pré-escolar. Neste sentido, tem a trabalhar na sua equipa a investigadora mestranda Cristiana Mercê, sendo o responsável pela investigação o Professor Doutor David Paulo Ramalheira Catela.

A desordem no desenvolvimento da coordenação motora carateriza-se por uma dificuldade em realizar tarefas motoras que seriam dominadas em determinado momento do desenvolvimento. Esta desordem pode ter consequências na capacidade de escrita, prejudicando o rendimento escolar, como na capacidade de realizar habilidades com outras crianças (por exemplo, jogar à bola ou dançar), prejudicando a interação social e isolando a criança. Esta desordem pode detetar-se em idades tão baixas como os 3 anos, possibilitando intervenção o mais cedo possível.

A criança realizará tarefas motoras, definidas para o seu nível etário, como desenhar linhas, lançar e receber uma bola, equilibrar-se de pé, atarraxar, segurar escova de dentes como se fosse lavá-los, usar borracha para apagar, ou agarrar um brinquedo em várias posições no espaço. As tarefas serão apresentadas como um jogo. A criança será filmada. As recolhas decorrerão nas instalações do jardim de infância, durante o período normal de estadia da criança, e na presença de pessoa que seja conhecida da criança. As recolhas não implicam qualquer tipo de risco presente ou futuro para a criança. As datas das recolhas serão definidas após consentimento informado de V. Ex.ª. Mesmo com autorização de V. Ex.ª, a criança só participará se der o seu assentimento, quer dizer, se assim o permitir. Ser-lhe-á dito o que vai fazer, e, ser-lhe-á perguntado se deseja fazer ou não. Para se poder caraterizar o conjunto das crianças, serão recolhidos através do boletim de saúde infantil e juvenil os seguintes dados de cada criança: data de nascimento; sexo; peso; comprimento e perímetro cefálico ao nascimento; índice APGAR ao 1.º e ao 5.º minuto; e, tipo de gravidez. Pelo que agradecemos desde já a sua colaboração na disponibilização do referido boletim, quando for solicitado.

O tratamento dos dados recolhidos é confidencial e anónimo, isto é, nas folhas de registo das observações nunca constará o nome da criança, do pai, da mãe, ou qualquer outro elemento identificativo, mas um código correspondente. Se detetada desordem motora, os dados da vossa criança ser-vos-ão disponibilizados e esclarecidos.

Deste modo, vimos solicitar a V. Ex.ª que se digne autorizar a referida experimentadora a incluir a vossa criança no referido estudo.

O responsável pelo estudo está inteiramente à disposição de V. Ex.ª para quaisquer esclarecimentos adicionais.

Antecipadamente gratos pela atenção dispensada,

Rio Maior, em 20 de março de 2015
O Responsável

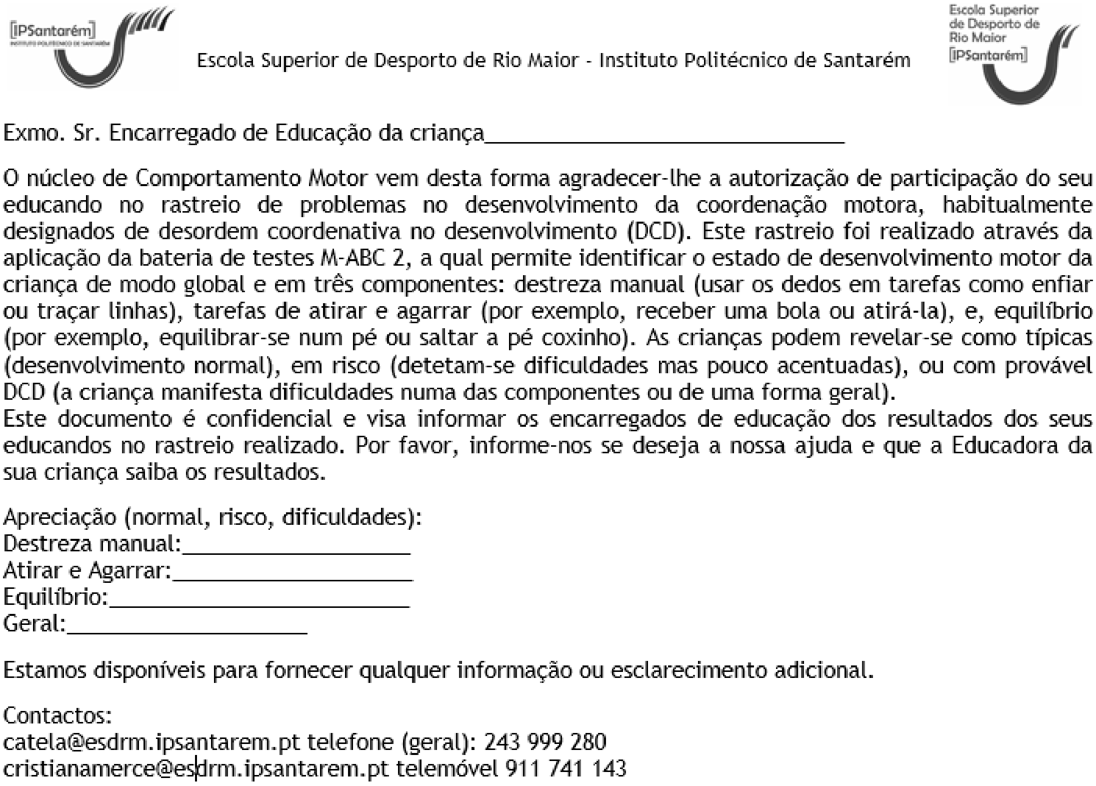
Contactos: catela@esdrm.ipsantarem.pt Telefone (geral): 243 999 280
cristianamerce@esdrm.ipsantarem.pt, telemóvel 911 741 143

-------------------(Separar por aqui e ficar com Pedido de Consentimento Informado)-------------------

Eu (nome) ____, compreendi as informações que me foram prestadas e autorizo a minha criança (nome) ____,
a participar no estudo sobre desordem coordenativa no desenvolvimento.
____________________________ (local), ____ (ano)/ ____ (mês)/ ____ (dia)

____ (Assinatura)

Appendix 2 – Personal report of MABC-2 scores for parents



Escola Superior de Desporto de Rio Maior - Instituto Politécnico de Santarém

Exmo. Sr. Encarregado de Educação da criança______________________________

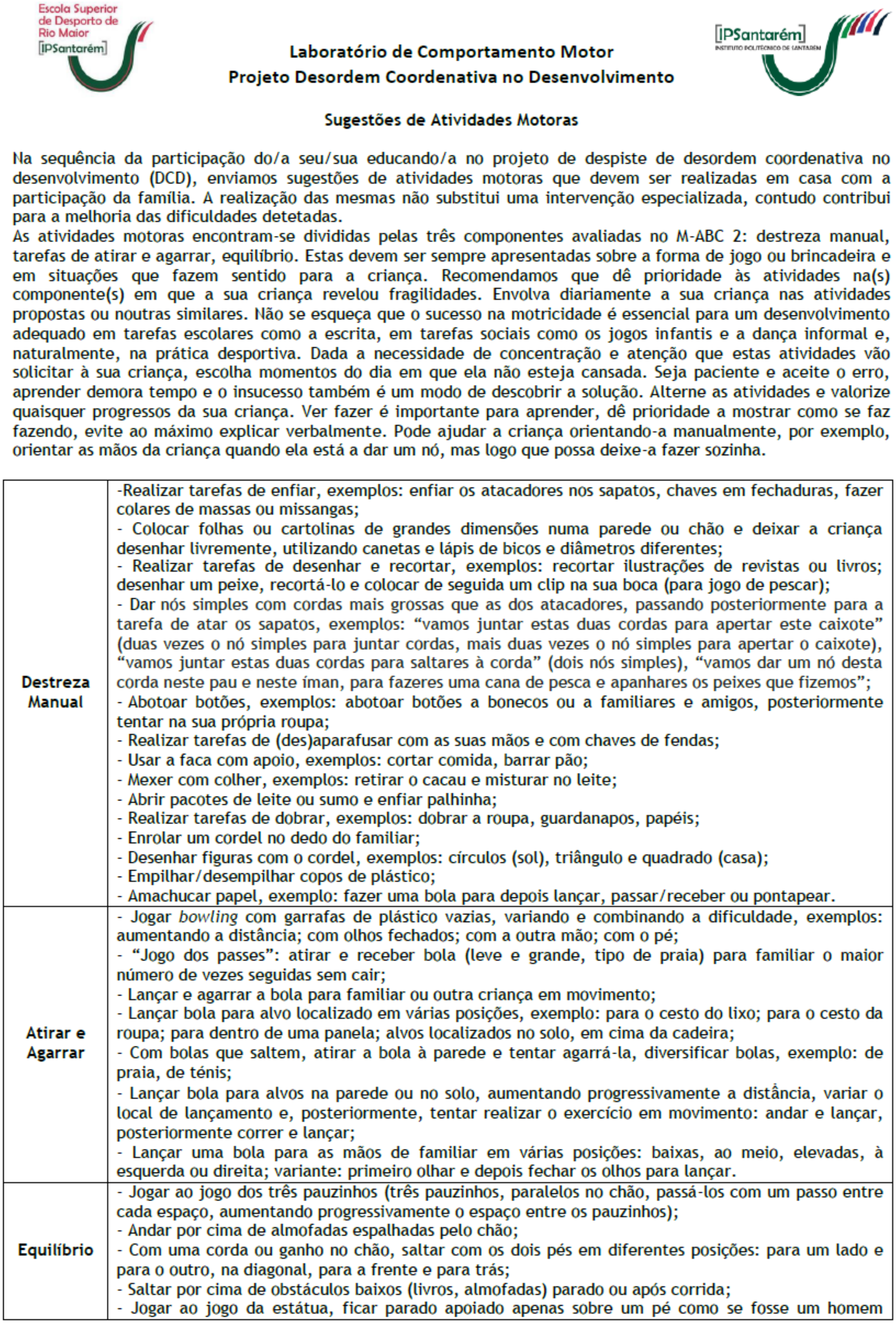
O núcleo de Comportamento Motor vem desta forma agradecer-lhe a autorização de participação do seu educando no rastreio de problemas no desenvolvimento da coordenação motora, habitualmente designados de desordem coordenativa no desenvolvimento (DCD). Este rastreio foi realizado através da aplicação da bateria de testes M-ABC 2, a qual permite identificar o estado de desenvolvimento motor da criança de modo global e em três componentes: destreza manual (usar os dedos em tarefas como enfiar ou traçar linhas), tarefas de atirar e agarrar (por exemplo, receber uma bola ou atirá-la), e, equilíbrio (por exemplo, equilibrar-se num pé ou saltar a pé coxinho). As crianças podem revelar-se como típicas (desenvolvimento normal), em risco (detetam-se dificuldades mas pouco acentuadas), ou com provável DCD (a criança manifesta dificuldades numa das componentes ou de uma forma geral).
Este documento é confidencial e visa informar os encarregados de educação dos resultados dos seus educandos no rastreio realizado. Por favor, informe-nos se deseja a nossa ajuda e que a Educadora da sua criança saiba os resultados.

Apreciação (normal, risco, dificuldades):
Destreza manual:___________________
Atirar e Agarrar:___________________
Equilíbrio:_________________________
Geral:____________________

Estamos disponíveis para fornecer qualquer informação ou esclarecimento adicional.

Contactos:
catela@esdrm.ipsantarem.pt telefone (geral): 243 999 280
cristianamerce@esdrm.ipsantarem.pt telemóvel 911 741 143

Appendix 3 – Motor activities’ suggestions



Escola Superior de Desporto de Rio Maior [IPSantarém]

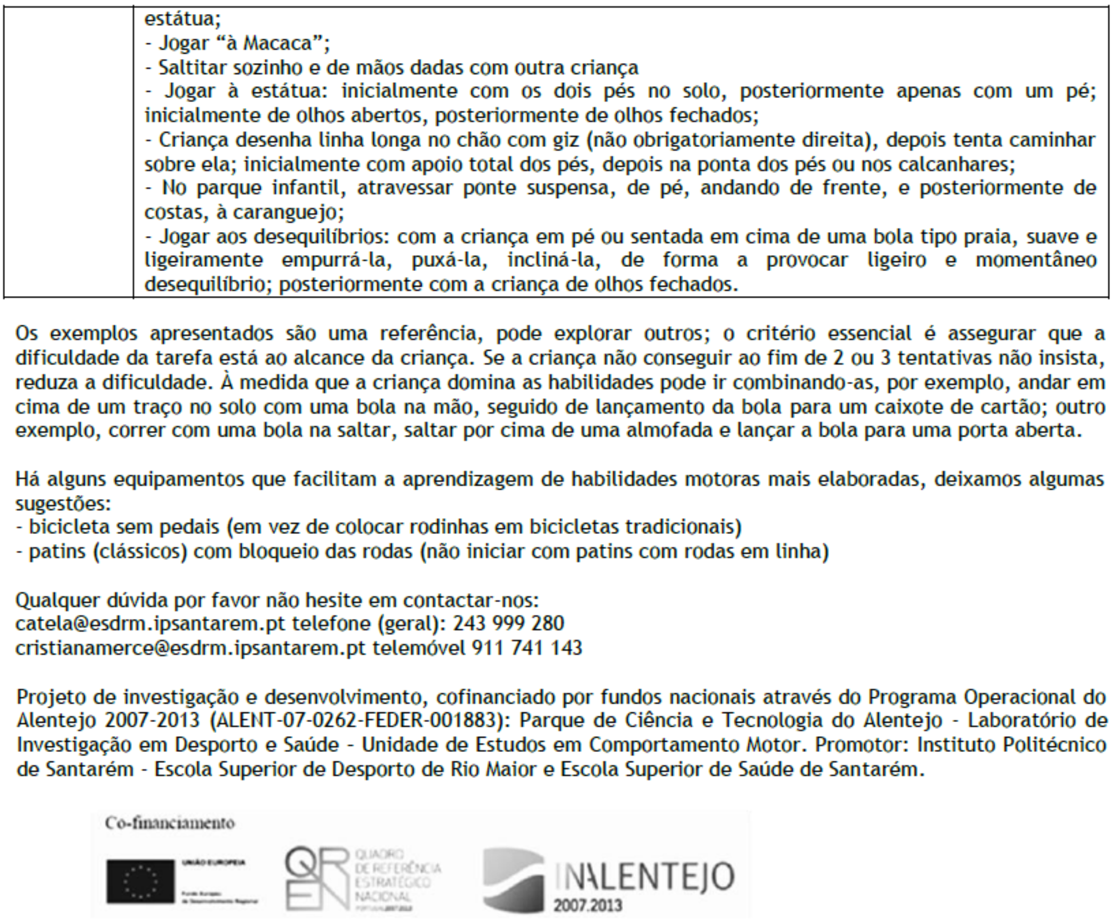
[IPSantarém] INSTITUTO POLITÉCNICO DE SANTARÉM

Laboratório de Comportamento Motor
Projeto Desordem Coordenativa no Desenvolvimento

Sugestões de Atividades Motoras

Na sequência da participação do/a seu/sua educando/a no projeto de despiste de desordem coordenativa no desenvolvimento (DCD), enviamos sugestões de atividades motoras que devem ser realizadas em casa com a participação da família. A realização das mesmas não substitui uma intervenção especializada, contudo contribui para a melhoria das dificuldades detetadas.
As atividades motoras encontram-se divididas pelas três componentes avaliadas no M-ABC 2: destreza manual, tarefas de atirar e agarrar, equilíbrio. Estas devem ser sempre apresentadas sobre a forma de jogo ou brincadeira e em situações que fazem sentido para a criança. Recomendamos que dê prioridade às atividades na(s) componente(s) em que a sua criança revelou fragilidades. Envolva diariamente a sua criança nas atividades propostas ou noutras similares. Não se esqueça que o sucesso na motricidade é essencial para um desenvolvimento adequado em tarefas escolares como a escrita, em tarefas sociais como os jogos infantis e a dança informal e, naturalmente, na prática desportiva. Dada a necessidade de concentração e atenção que estas atividades vão solicitar à sua criança, escolha momentos do dia em que ela não esteja cansada. Seja paciente e aceite o erro, aprender demora tempo e o insucesso também é um modo de descobrir a solução. Alterne as atividades e valorize quaisquer progressos da sua criança. Ver fazer é importante para aprender, dê prioridade a mostrar como se faz fazendo, evite ao máximo explicar verbalmente. Pode ajudar a criança orientando-a manualmente, por exemplo, orientar as mãos da criança quando ela está a dar um nó, mas logo que possa deixe-a fazer sozinha.

Destreza Manual	-Realizar tarefas de enfiar, exemplos: enfiar os atacadores nos sapatos, chaves em fechaduras, fazer colares de massas ou missangas; - Colocar folhas ou cartolinas de grandes dimensões numa parede ou chão e deixar a criança desenhar livremente, utilizando canetas e lápis de bicos e diâmetros diferentes; - Realizar tarefas de desenhar e recortar, exemplos: recortar ilustrações de revistas ou livros; desenhar um peixe, recortá-lo e colocar de seguida um clip na sua boca (para jogo de pescar); - Dar nós simples com cordas mais grossas que as dos atacadores, passando posteriormente para a tarefa de atar os sapatos, exemplos: “vamos juntar estas duas cordas para apertar este caixote” (duas vezes o nó simples para juntar cordas, mais duas vezes o nó simples para apertar o caixote), “vamos juntar estas duas cordas para saltares à corda” (dois nós simples), “vamos dar um nó desta corda neste pau e neste íman, para fazeres uma cana de pesca e apanhares os peixes que fizemos”; - Abotoar botões, exemplos: abotoar botões a bonecos ou a familiares e amigos, posteriormente tentar na sua própria roupa; - Realizar tarefas de (des)aparafusar com as suas mãos e com chaves de fendas; - Usar a faca com apoio, exemplos: cortar comida, barrar pão; - Mexer com colher, exemplos: retirar o cacau e misturar no leite; - Abrir pacotes de leite ou sumo e enfiar palhinha; - Realizar tarefas de dobrar, exemplos: dobrar a roupa, guardanapos, papéis; - Enrolar um cordel no dedo do familiar; - Desenhar figuras com o cordel, exemplos: círculos (sol), triângulo e quadrado (casa); - Empilhar/desempilhar copos de plástico; - Amachucar papel, exemplo: fazer uma bola para depois lançar, passar/receber ou pontapear.
Atirar e Agarrar	- Jogar *bowling* com garrafas de plástico vazias, variando e combinando a dificuldade, exemplos: aumentando a distância; com olhos fechados; com a outra mão; com o pé; - “Jogo dos passes”: atirar e receber bola (leve e grande, tipo de praia) para familiar o maior número de vezes seguidas sem cair; - Lançar e agarrar a bola para familiar ou outra criança em movimento; - Lançar bola para alvo localizado em várias posições, exemplo: para o cesto do lixo; para o cesto da roupa; para dentro de uma panela; alvos localizados no solo, em cima da cadeira; - Com bolas que saltem, atirar a bola à parede e tentar agarrá-la, diversificar bolas, exemplo: de praia, de ténis; - Lançar bola para alvos na parede ou no solo, aumentando progressivamente a distância, variar o local de lançamento e, posteriormente, tentar realizar o exercício em movimento: andar e lançar, posteriormente correr e lançar; - Lançar uma bola para as mãos de familiar em várias posições: baixas, ao meio, elevadas, à esquerda ou direita; variante: primeiro olhar e depois fechar os olhos para lançar.
Equilíbrio	- Jogar ao jogo dos três pauzinhos (três pauzinhos, paralelos no chão, passá-los com um passo entre cada espaço, aumentando progressivamente o espaço entre os pauzinhos); - Andar por cima de almofadas espalhadas pelo chão; - Com uma corda ou ganho no chão, saltar com os dois pés em diferentes posições: para um lado e para o outro, na diagonal, para a frente e para trás; - Saltar por cima de obstáculos baixos (livros, almofadas) parado ou após corrida; - Jogar ao jogo da estátua, ficar parado apoiado apenas sobre um pé como se fosse um homem



	estátua; - Jogar "à Macaca"; - Saltitar sozinho e de mãos dadas com outra criança - Jogar à estátua: inicialmente com os dois pés no solo, posteriormente apenas com um pé; inicialmente de olhos abertos, posteriormente de olhos fechados; - Criança desenha linha longa no chão com giz (não obrigatoriamente direita), depois tenta caminhar sobre ela; inicialmente com apoio total dos pés, depois na ponta dos pés ou nos calcanhares; - No parque infantil, atravessar ponte suspensa, de pé, andando de frente, e posteriormente de costas, à caranguejo; - Jogar aos desequilíbrios: com a criança em pé ou sentada em cima de uma bola tipo praia, suave e ligeiramente empurrá-la, puxá-la, incliná-la, de forma a provocar ligeiro e momentâneo desequilíbrio; posteriormente com a criança de olhos fechados.

Os exemplos apresentados são uma referência, pode explorar outros; o critério essencial é assegurar que a dificuldade da tarefa está ao alcance da criança. Se a criança não conseguir ao fim de 2 ou 3 tentativas não insista, reduza a dificuldade. À medida que a criança domina as habilidades pode ir combinando-as, por exemplo, andar em cima de um traço no solo com uma bola na mão, seguido de lançamento da bola para um caixote de cartão; outro exemplo, correr com uma bola na saltar, saltar por cima de uma almofada e lançar a bola para uma porta aberta.

Há alguns equipamentos que facilitam a aprendizagem de habilidades motoras mais elaboradas, deixamos algumas sugestões:
- bicicleta sem pedais (em vez de colocar rodinhas em bicicletas tradicionais)
- patins (clássicos) com bloqueio das rodas (não iniciar com patins com rodas em linha)

Qualquer dúvida por favor não hesite em contactar-nos:
catela@esdrm.ipsantarem.pt telefone (geral): 243 999 280
cristianamerce@esdrm.ipsantarem.pt telemóvel 911 741 143

Projeto de investigação e desenvolvimento, cofinanciado por fundos nacionais através do Programa Operacional do Alentejo 2007-2013 (ALENT-07-0262-FEDER-001883): Parque de Ciência e Tecnologia do Alentejo - Laboratório de Investigação em Desporto e Saúde - Unidade de Estudos em Comportamento Motor. Promotor: Instituto Politécnico de Santarém - Escola Superior de Desporto de Rio Maior e Escola Superior de Saúde de Santarém.

Co-financiamento

Appendix 4 – Data treatment for chapter III

Estatísticas Descritivas

	N	Mínimo	Máximo	Média	Desvio Padrão
Idade Décimal	46	3,4	4,4	3,895	,2561
N válido (listwise)	46				

Frequências

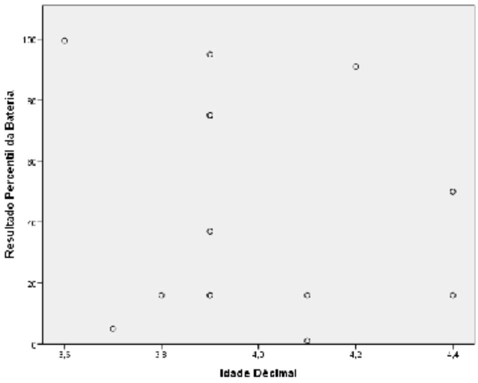
Sexo

		Frequência	Porcentagem	Porcentagem válida	Porcentagem cumulativa
Válido	Feminino	25	54,3	54,3	54,3
	Masculino	21	45,7	45,7	100,0
	Total	46	100,0	100,0	

Crosstabs

		Sexo		Total
		Feminino	Masculino	
Definição das crianças em DCD, Tipica, risco	Tipica	20	17	37
	em Risco	4	3	7
	com DCD	1	1	2
Total		25	21	46

GGraph



Correlations

Correlations

			Idade Décimal	Resultado Percentil da Bateria
Spearman's rho	Idade Décimal	Correlation Coefficient	1,000	-,096
		Sig. (2-tailed)	.	,743
		N	14	14
	Resultado Percentil da Bateria	Correlation Coefficient	-,096	1,000
		Sig. (2-tailed)	,743	.
		N	14	14

Nonparametric Correlations

Correlations

		Idade Décimal	Resultado Percentil da Bateria
Idade Décimal	Pearson Correlation	1	-,149
	Sig. (2-tailed)		,612
	N	14	14
Resultado Percentil da Bateria	Pearson Correlation	-,149	1
	Sig. (2-tailed)	,612	
	N	14	14

Descritivas

Estatísticas Descritivas

	N	Mínimo	Máximo	Média	Desvio Padrão
Resultado Total da Bateria	37	68	116	87,49	10,455
Resultado Padrão da Bateria	37	8	19	12,19	2,787
Resultado Percentil da Bateria	37	25	100	69,01	23,980
N válido (listwise)	37				

Estatísticas Descritivas

	N	Mínimo	Máximo	Média	Desvio Padrão
Resultado Total da Bateria	7	61	67	64,86	2,340
Resultado Padrão da Bateria	7	6	7	6,86	,378
Resultado Percentil da Bateria	7	9	16	15,00	2,646
N válido (listwise)	7				

Estatísticas Descritivas

	N	Mínimo	Máximo	Média	Desvio Padrão
Resultado Total da Bateria	2	39	52	45,50	9,192
Resultado Padrão da Bateria	2	3	5	4,00	1,414
Resultado Percentil da Bateria	2	1	5	3,00	2,828
N válido (listwise)	2				

Estatísticas Descritivas

	N	Mínimo	Máximo	Média	Desvio Padrão
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	37	9	100	65,55	30,248
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	37	2	100	58,80	30,777
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	37	9	100	68,21	22,472
N válido (listwise)	37				

Estatísticas Descritivas

	N	Mínimo	Máximo	Média	Desvio Padrão
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	7	9	37	23,86	11,481
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	7	9	63	27,00	20,298
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	7	9	63	24,71	19,006
N válido (listwise)	7				

Estatísticas Descritivas

	N	Mínimo	Máximo	Média	Desvio Padrão
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	2	1	9	5,00	5,657
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	2	5	5	5,00	,000
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	2	5	16	10,50	7,778
N válido (listwise)	2				

Definição das crianças em DCD, Tipica, risco

		Frequência	Porcentagem	Porcentagem válida	Porcentagem cumulativa
Válido	Tipica	37	80,4	80,4	80,4
	em Risco	7	15,2	15,2	95,7
	com DCD	2	4,3	4,3	100,0
	Total	46	100,0	100,0	

Frequências

Mão usada para escrever – típicos

		Frequência	Porcentagem	Porcentagem válida	Porcentagem cumulativa
Válido	Esquerda	3	8,1	8,1	8,1
	Direita	34	91,9	91,9	100,0
	Total	37	100,0	100,0	

Mão usada para escrever – risco

		Frequência	Porcentagem	Porcentagem válida	Porcentagem cumulativa
Válido	Esquerda	2	11,8	11,8	11,8
	Direita	15	88,2	88,2	100,0
	Total	17	100,0	100,0	

NPar Tests

Kruskal-Wallis Test

Ranks

	Definição das crianças em DCD, Tipica, risco	N	Mean Rank
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	Tipica	37	26,54
	em Risco	7	13,43
	com DCD	2	2,50
	Total	46	
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	Tipica	37	27,08
	em Risco	7	10,50
	com DCD	2	2,75
	Total	46	
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	Tipica	37	27,38
	em Risco	7	8,71
	com DCD	2	3,50

	Total	46	

Test Statistics[a,b]

	Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	Resultados da Percentil Destreza Manual (DM1, DM2, DM3)
Chi-Square	10,833	14,179	16,267
Df	2	2	2
Asymp. Sig.	,004	,001	,000

a. Kruskal Wallis Test

b. Grouping Variable: Definição das crianças em DCD, Tipica, risco

Mann-Whitney Test

Ranks

	Definição das crianças em DCD, Tipica, risco	N	Mean Rank	Sum of Ranks
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	Tipica	37	20,97	776,00
	com DCD	2	2,00	4,00
	Total	39		
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	Tipica	37	20,95	775,00
	com DCD	2	2,50	5,00
	Total	39		
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	Tipica	37	20,96	775,50
	com DCD	2	2,25	4,50
	Total	39		

Test Statistics[a]

	Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)
Mann-Whitney U	1,000	2,000	1,500
Wilcoxon W	4,000	5,000	4,500
Z	-2,316	-2,240	-2,277
Asymp. Sig. (2-tailed)	,021	,025	,023
Exact Sig. [2*(1-tailed Sig.)]	,005[b]	,011[b]	,005[b]

a. Grouping Variable: Definição das crianças em DCD, Tipica, risco

b. Not corrected for ties.

Mann-Whitney Test

Ranks

	Definição das crianças em DCD, Tipica, risco	N	Mean Rank	Sum of Ranks
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	Tipica	37	25,41	940,00
	em Risco	7	7,14	50,00
	Total	44		
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	Tipica	37	24,59	910,00
	em Risco	7	11,43	80,00
	Total	44		
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	Tipica	37	25,12	929,50
	em Risco	7	8,64	60,50
	Total	44		

Test Statistics[a]

	Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)
Mann-Whitney U	22,000	52,000	32,500
Wilcoxon W	50,000	80,000	60,500
Z	-3,478	-2,500	-3,136
Asymp. Sig. (2-tailed)	,001	,012	,002
Exact Sig. [2*(1-tailed Sig.)]	,000[b]	,011[b]	,001[b]

a. Grouping Variable: Definição das crianças em DCD, Tipica, risco

b. Not corrected for ties.

Mann-Whitney Test

Ranks

	Definição das crianças em DCD, Tipica, risco	N	Mean Rank	Sum of Ranks
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	em Risco	7	5,57	39,00
	com DCD	2	3,00	6,00
	Total	9		
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	em Risco	7	6,00	42,00
	com DCD	2	1,50	3,00
	Total	9		
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	em Risco	7	5,86	41,00
	com DCD	2	2,00	4,00
	Total	9		

Test Statistics[a]

	Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)
Mann-Whitney U	3,000	,000	1,000
Wilcoxon W	6,000	3,000	4,000
Z	-1,283	-2,103	-1,826
Asymp. Sig. (2-tailed)	,200	,035	,068
Exact Sig. [2*(1-tailed Sig.)]	,333[b]	,056[b]	,111[b]

a. Grouping Variable: Definição das crianças em DCD, Tipica, risco

b. Not corrected for ties.

Friedman Test

Ranks

	Mean Rank
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	2,04
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	1,86
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	2,09

Test Statistics[a]

N	37
Chi-Square	1,145
Df	2
Asymp. Sig.	,564

a. Friedman Test

Friedman Test

Ranks

	Mean Rank
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	1,93
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	2,00
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	2,07

Test Statistics[a]

N	7
Chi-Square	,074
Df	2
Asymp. Sig.	,964

a. Friedman Test

Friedman Test

Ranks

	Mean Rank
Resultados da Percentil Destreza Manual (DM1, DM2, DM3)	2,75
Resultados da Percentil Agarrar e Atirar (AtAg1, AtAg2)	1,75
Resultados da Percentil Equilibrio 1(Eq1,Eq2,Eq3)	1,50

Test Statistics[a]

N	2
Chi-Square	2,000
Df	2
Asymp. Sig.	,368

a. Friedman Test

Appendix 5 – Data treatment for chapter IV

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Idade Décimal	14	3,6	4,4	3,979	,2359
Valid N (listwise)	14				

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Definição das crianças em DCD, Tipica, risco * Sexo	14	100,0%	0	0,0%	14	100,0%

Definição das crianças em DCD, Tipica, risco * Sexo Crosstabulation

Count

		Sexo		Total
		Feminino	Masculino	
Definição das crianças em DCD, Tipica, risco	Tipica	4	3	7
	em Risco	3	2	5
	com DCD	1	1	2
Total		8	6	14

Descriptives - Vertex

Descriptive Statistics DCD – SEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,22	,22	,2195	,00214
Det	2	1,00	1,00	,9985	,00144
Meanline	2	37,64	41,76	39,6993	2,91741
Maxline	2	870,00	879,00	874,5000	6,36396
Entropy	2	4,31	4,44	4,3754	,09379
Laminarity	2	1,00	1,00	,9993	,00066
Vmax	2	155,00	219,00	187,0000	45,25483
SampleEntropy	2	,00	,01	,0032	,00448
Lyapunov	2	4,75	13,33	9,0410	6,06793
Valid N (listwise)	2				

Descriptive Statistics DCD - SEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,15	,31	,2334	,11118
Det	2	1,00	1,00	,9976	,00265
Meanline	2	33,54	88,37	60,9561	38,76986
Maxline	2	867,00	870,00	868,5000	2,12132
Entropy	2	4,19	4,24	4,2182	,03527
Laminarity	2	1,00	1,00	,9985	,00190
Vmax	2	116,00	417,00	266,5000	212,83914
SampleEntropy	2	,00	,00	,0024	,00051
Lyapunov	2	1,42	10,44	5,9301	6,37820
Valid N (listwise)	2				

Descriptive Statistics DCD – SD

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,22	,23	,2243	,00493
Det	2	,99	1,00	,9931	,00964
Meanline	2	28,69	77,44	53,0623	34,47166
Maxline	2	858,00	873,00	865,5000	10,60660
Entropy	2	3,71	4,83	4,2729	,79405
Laminarity	2	,99	1,00	,9955	,00635
Vmax	2	261,00	361,00	311,0000	70,71068
SampleEntropy	2	,00	,00	,0010	,00106
Lyapunov	2	,90	5,24	3,0713	3,07061
Valid N (listwise)	2				

Descriptive Statistics DCD - DEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,13	,14	,1363	,00337
Det	2	,99	1,00	,9965	,00441
Meanline	2	24,94	40,88	32,9099	11,27102
Maxline	2	849,00	855,00	852,0000	4,24264
Entropy	2	3,74	4,33	4,0362	,41760
Laminarity	2	1,00	1,00	,9978	,00292
Vmax	2	130,00	212,00	171,0000	57,98276
SampleEntropy	2	,00	,00	,0000	,00004
Lyapunov	2	5,09	5,99	5,5361	,63690
Valid N (listwise)	2				

Descriptive Statistics DCD - DEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,07	,20	,1369	,08946
Det	2	,99	1,00	,9953	,00528
Meanline	2	25,75	29,10	27,4245	2,36972
Maxline	2	840,00	870,00	855,0000	21,21320
Entropy	2	3,65	3,96	3,8061	,21774
Laminarity	2	,99	1,00	,9973	,00340
Vmax	2	66,00	184,00	125,0000	83,43860
SampleEntropy	2	,00	,00	,0027	,00148
Lyapunov	2	7,56	14,17	10,8648	4,66936
Valid N (listwise)	2				

Descriptive Statistics R - SEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,17	,55	,3428	,14607
Det	5	1,00	1,00	,9998	,00014
Meanline	5	37,94	207,26	101,0040	63,54747
Maxline	5	855,00	874,00	865,4000	8,08084
Entropy	5	4,31	5,85	4,9891	,56748
Laminarity	5	1,00	1,00	,9999	,00007
Vmax	5	174,00	635,00	380,4000	184,34153
SampleEntropy	5	,00	,01	,0026	,00208
Lyapunov	5	1,83	7,62	4,3471	2,20806
Valid N (listwise)	5				

Descriptive Statistics R - SEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,14	,34	,2300	,09252
Det	5	,99	1,00	,9976	,00457
Meanline	5	38,65	97,31	55,5889	24,22561
Maxline	5	836,00	886,00	865,0000	21,65641
Entropy	5	4,14	4,69	4,4016	,22033
Laminarity	5	,99	1,00	,9986	,00294
Vmax	5	169,00	335,00	249,2000	70,56699
SampleEntropy	5	,00	,01	,0017	,00276
Lyapunov	5	,29	9,74	4,3716	3,85095
Valid N (listwise)	5				

Descriptive Statistics R - SD

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,14	,42	,2714	,11009
Det	5	1,00	1,00	,9997	,00018
Meanline	5	39,66	85,60	53,3741	18,51646
Maxline	5	855,00	884,00	867,6000	12,21884
Entropy	5	4,18	5,19	4,6267	,36250
Laminarity	5	1,00	1,00	,9999	,00012
Vmax	5	178,00	298,00	245,8000	43,69439
SampleEntropy	5	,00	,01	,0016	,00223
Lyapunov	5	,14	10,73	4,0940	4,43787
Valid N (listwise)	5				

Descriptive Statistics R - DEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,27	,35	,2920	,03636
Det	5	1,00	1,00	,9998	,00017
Meanline	5	47,71	104,97	68,0588	23,00242
Maxline	5	858,00	876,00	866,0000	7,34847
Entropy	5	4,56	5,19	4,8267	,23856
Laminarity	5	1,00	1,00	,9999	,00008
Vmax	5	191,00	413,00	311,4000	98,06274
SampleEntropy	5	,00	,00	,0000	,00004
Lyapunov	5	2,72	12,35	6,7710	3,84936
Valid N (listwise)	5				

Descriptive Statistics R - DEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,13	,41	,2436	,12647
Det	5	1,00	1,00	,9996	,00039
Meanline	5	23,09	83,94	49,4507	26,57945
Maxline	5	852,00	873,00	863,4000	7,76531
Entropy	5	3,82	5,00	4,4261	,56808
Laminarity	5	1,00	1,00	,9998	,00020
Vmax	5	80,00	452,00	249,2000	149,70872
SampleEntropy	5	,00	,01	,0023	,00482
Lyapunov	5	4,56	9,07	7,1776	1,70618
Valid N (listwise)	5				

Descriptive Statistics T -SEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,18	,48	,2962	,10204
Det	7	1,00	1,00	,9997	,00025
Meanline	7	26,41	140,97	78,9846	41,17440
Maxline	7	834,00	873,00	854,7143	14,09154
Entropy	7	3,96	5,45	4,7522	,54349
Laminarity	7	1,00	1,00	,9999	,00013
Vmax	7	145,00	700,00	366,0000	178,90221
SampleEntropy	7	,00	,03	,0076	,00888
Lyapunov	7	,59	11,15	4,6966	4,06093
Valid N (listwise)	7				

Descriptive Statistics T- SEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,14	,29	,2299	,05347
Det	7	1,00	1,00	,9997	,00019
Meanline	7	39,32	108,70	58,0820	23,82418
Maxline	7	820,00	873,00	853,8571	18,15148
Entropy	7	4,31	5,07	4,6072	,27033
Laminarity	7	1,00	1,00	,9999	,00009
Vmax	7	155,00	374,00	235,8571	74,96317
SampleEntropy	7	,00	,02	,0074	,00675
Lyapunov	7	,37	8,56	3,2477	3,21546
Valid N (listwise)	7				

Descriptive Statistics T - SD

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,19	,29	,2444	,03846
Det	7	1,00	1,00	,9998	,00011
Meanline	7	34,52	112,36	65,0652	25,20727
Maxline	7	836,00	876,00	858,0000	15,88500
Entropy	7	4,29	5,24	4,7801	,29806
Laminarity	7	1,00	1,00	,9999	,00005
Vmax	7	155,00	352,00	237,1429	64,29471
SampleEntropy	7	,00	,01	,0024	,00410
Lyapunov	7	-,23	11,06	3,6681	3,64315
Valid N (listwise)	7				

Descriptive Statistics T - DEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,15	,32	,2418	,06105
Det	7	1,00	1,00	,9998	,00009
Meanline	7	41,45	79,28	56,9674	11,86665
Maxline	7	840,00	876,00	864,5714	11,92836
Entropy	7	4,35	5,00	4,6962	,22912
Laminarity	7	1,00	1,00	,9999	,00005
Vmax	7	179,00	351,00	272,1429	50,79183
SampleEntropy	7	,00	,00	,0002	,00030
Lyapunov	7	,28	13,44	5,5533	4,37610
Valid N (listwise)	7				

Descriptive Statistics T - DEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,11	,27	,1724	,05271
Det	7	1,00	1,00	,9996	,00013
Meanline	7	35,59	48,72	41,6575	6,27304
Maxline	7	849,00	876,00	861,8571	10,63686
Entropy	7	4,08	4,65	4,3381	,20134
Laminarity	7	1,00	1,00	,9999	,00006
Vmax	7	93,00	288,00	200,8571	76,26146
SampleEntropy	7	,00	,00	,0016	,00138
Lyapunov	7	1,74	9,46	5,7697	2,91912
Valid N (listwise)	7				

Descriptives C7

Descriptive Statistics DCD - SEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,15	,19	,1697	,03439
Det	2	,99	1,00	,9960	,00447
Meanline	2	32,69	33,85	33,2725	,82345
Maxline	2	848,00	868,00	858,0000	14,14214
Entropy	2	4,06	4,17	4,1196	,07821
Laminarity	2	1,00	1,00	,9974	,00312
Vmax	2	194,00	217,00	205,5000	16,26346
SampleEntropy	2	,00	,02	,0085	,01189
Lyapunov	2	1,56	7,63	4,5931	4,29543
Valid N (listwise)	2				

Descriptive Statistics DCD - SEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,17	,31	,2389	,10275
Det	2	,93	1,00	,9654	,04829
Meanline	2	9,87	39,04	24,4568	20,62180
Maxline	2	858,00	888,00	873,0000	21,21320
Entropy	2	2,28	4,34	3,3110	1,46000
Laminarity	2	,95	1,00	,9768	,03268
Vmax	2	136,00	152,00	144,0000	11,31371
SampleEntropy	2	,01	,07	,0368	,04191
Lyapunov	2	6,07	11,03	8,5481	3,50339
Valid N (listwise)	2				

Descriptive Statistics DCD - SD

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,21	,25	,2312	,03133
Det	2	,99	1,00	,9967	,00458
Meanline	2	50,40	95,34	72,8683	31,77827
Maxline	2	831,00	861,00	846,0000	21,21320
Entropy	2	4,08	4,92	4,5009	,59405
Laminarity	2	1,00	1,00	,9978	,00306
Vmax	2	269,00	511,00	390,0000	171,11984
SampleEntropy	2	,00	,01	,0048	,00245
Lyapunov	2	2,72	4,77	3,7466	1,44536
Valid N (listwise)	2				

Descriptive Statistics DCD - DEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,20	,22	,2098	,01153
Det	2	,99	1,00	,9937	,00873
Meanline	2	22,37	69,18	45,7785	33,09824
Maxline	2	861,00	872,00	866,5000	7,77817
Entropy	2	3,65	4,86	4,2550	,85045
Laminarity	2	,99	1,00	,9959	,00570
Vmax	2	132,00	314,00	223,0000	128,69343
SampleEntropy	2	,00	,00	,0028	,00099
Lyapunov	2	1,76	10,10	5,9285	5,89844
Valid N (listwise)	2				

Descriptive Statistics DCD - DEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	2	,07	,20	,1333	,09237
Det	2	,98	,99	,9887	,00596
Meanline	2	10,97	19,84	15,4061	6,27448
Maxline	2	855,00	872,00	863,5000	12,02082
Entropy	2	2,92	3,49	3,2031	,40532
Laminarity	2	,99	1,00	,9934	,00500
Vmax	2	88,00	157,00	122,5000	48,79037
SampleEntropy	2	,01	,03	,0162	,01392
Lyapunov	2	13,48	14,53	14,0065	,74512
Valid N (listwise)	2				

Descriptive Statistics R - SEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,04	,65	,3056	,22942
Det	5	1,00	1,00	,9996	,00059
Meanline	5	24,88	251,18	96,5675	91,76005
Maxline	5	805,00	876,00	854,0000	28,46928
Entropy	5	3,50	5,88	4,7492	,90432
Laminarity	5	1,00	1,00	,9999	,00009
Vmax	5	70,00	704,00	343,6000	251,20967
SampleEntropy	5	,00	,03	,0109	,01406
Lyapunov	5	,78	9,39	5,9749	3,30264
Valid N (listwise)	5				

Descriptive Statistics R - SEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,15	,36	,2474	,08478
Det	5	,98	1,00	,9963	,00766
Meanline	5	36,00	153,07	70,2244	48,35991
Maxline	5	860,00	870,00	864,4000	4,15933
Entropy	5	3,81	5,05	4,5077	,49515
Laminarity	5	,99	1,00	,9975	,00532
Vmax	5	195,00	576,00	327,8000	169,97264
SampleEntropy	5	,00	,02	,0060	,01029
Lyapunov	5	-,49	8,16	3,5023	3,27847
Valid N (listwise)	5				

Descriptive Statistics R – SD

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,24	,43	,3069	,08579
Det	5	1,00	1,00	,9996	,00074
Meanline	5	39,04	86,79	64,5498	22,69563
Maxline	5	855,00	880,00	870,0000	9,82344
Entropy	5	4,36	5,01	4,6810	,29839
Laminarity	5	1,00	1,00	,9997	,00044
Vmax	5	196,00	553,00	301,2000	144,65545
SampleEntropy	5	,00	,01	,0027	,00430
Lyapunov	5	,77	17,30	6,6396	6,66814
Valid N (listwise)	5				

Descriptive Statistics R – DOA

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,12	,64	,2944	,20586
Det	5	1,00	1,00	,9989	,00180
Meanline	5	19,51	157,07	60,9595	55,01690
Maxline	5	852,00	876,00	865,2000	10,94075
Entropy	5	3,66	5,30	4,4493	,63020
Laminarity	5	1,00	1,00	,9996	,00070
Vmax	5	80,00	684,00	273,6000	235,63701
SampleEntropy	5	,00	,02	,0056	,00601
Lyapunov	5	-,53	16,84	6,4500	7,03245
Valid N (listwise)	5				

Descriptive Statistics R - DEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	5	,14	,19	,1817	,02105
Det	5	1,00	1,00	,9994	,00052
Meanline	5	28,20	69,17	41,9455	16,23066
Maxline	5	855,00	870,00	861,8000	5,58570
Entropy	5	3,90	4,84	4,3131	,34387
Laminarity	5	1,00	1,00	,9997	,00021
Vmax	5	119,00	296,00	222,2000	73,55406
SampleEntropy	5	,00	,01	,0033	,00318
Lyapunov	5	,63	13,68	6,4793	4,77377
Valid N (listwise)	5				

Descriptive Statistics T - SEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,17	,34	,2439	,06249
Det	7	1,00	1,00	,9992	,00125
Meanline	7	19,93	93,82	53,9017	26,49891
Maxline	7	834,00	879,00	865,5714	14,90925
Entropy	7	3,55	5,10	4,4037	,59807
Laminarity	7	1,00	1,00	,9996	,00053
Vmax	7	174,00	371,00	263,8571	75,14747
SampleEntropy	7	,01	,08	,0303	,02592
Lyapunov	7	4,64	9,81	7,3206	1,94421
Valid N (listwise)	7				

Descriptive Statistics T - SEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,13	,33	,2343	,08391
Det	7	1,00	1,00	,9993	,00055
Meanline	7	19,88	119,68	59,5436	35,54223
Maxline	7	840,00	879,00	858,4286	14,63850
Entropy	7	3,51	5,37	4,4495	,67634
Laminarity	7	1,00	1,00	,9997	,00026
Vmax	7	146,00	349,00	284,7143	76,69358
SampleEntropy	7	,00	,06	,0299	,02513
Lyapunov	7	-,24	14,68	5,7306	5,10818
Valid N (listwise)	7				

Descriptive Statistics T – SD

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,19	,45	,2937	,09657
Det	7	1,00	1,00	,9996	,00033
Meanline	7	33,92	129,46	70,4259	35,01070
Maxline	7	846,00	873,00	865,2857	9,30438
Entropy	7	4,01	5,35	4,7261	,47323
Laminarity	7	1,00	1,00	,9998	,00014
Vmax	7	203,00	532,00	347,7143	133,13992
SampleEntropy	7	,00	,06	,0168	,02384
*Lyapunov	7	-,94	12,13	4,5474	3,94344
Valid N (listwise)	7				

Descriptive Statistics T - DEO

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,14	,31	,2132	,06343
Det	7	1,00	1,00	,9995	,00030
Meanline	7	28,39	87,28	47,2506	22,50148
Maxline	7	848,00	876,00	864,4286	10,70603
Entropy	7	3,93	4,88	4,3706	,35552
Laminarity	7	1,00	1,00	,9998	,00013
Vmax	7	100,00	388,00	231,2857	92,92239
SampleEntropy	7	,00	,01	,0056	,00499
Lyapunov	7	3,73	12,05	6,7582	2,79544
Valid N (listwise)	7				

Descriptive Statistics T - DEC

	N	Minimum	Maximum	Mean	Std. Deviation
Rec	7	,10	,20	,1524	,03684
Det	7	1,00	1,00	,9990	,00057
Meanline	7	19,51	37,47	29,4089	6,81725
Maxline	7	858,00	876,00	866,5714	6,57919
Entropy	7	3,57	4,30	4,0164	,28944
Laminarity	7	1,00	1,00	,9996	,00026
Vmax	7	97,00	238,00	151,5714	47,78025
SampleEntropy	7	,01	,03	,0147	,00900
Lyapunov	7	3,13	14,55	8,8136	3,81080
Valid N (listwise)	7				

NPar Tests
Kruskal-Wallis Test – Posturography

Condition = SOA, Point = V

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	5,14
	R	5	9,00
	DCD	2	12,00
	Total	14	
Amplitude_AP	T	7	5,57
	R	5	8,40
	DCD	2	12,00
	Total	14	
Mean_Velocity_AP	T	7	5,14

	R	5	9,00
	DCD	2	12,00
	Total	14	

a. Condition = SOA, Point = V

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	5,180	4,033	5,180
df	2	2	2
Asymp. Sig.	,075	,133	,075

a. Condition = SOA, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = SOA, Point = C7

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	4,57
	R	5	10,20
	DCD	2	11,00
	Total	14	
Amplitude_AP	T	7	4,57
	R	5	10,20
	DCD	2	11,00
	Total	14	
Mean_Velocity_AP	T	7	4,57
	R	5	10,20
	DCD	2	11,00
	Total	14	

a. Condition = SOA, Point = C7

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	6,913	6,913	6,913
df	2	2	2
Asymp. Sig.	,032	,032	,032

a. Condition = SOA, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = SOF, Point = V

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	5,00
	R	5	11,00
	DCD	2	7,50
	Total	14	
Amplitude_AP	T	7	4,71
	R	5	11,80
	DCD	2	6,50
	Total	14	
Mean_Velocity_AP	T	7	5,00
	R	5	11,00
	DCD	2	7,50
	Total	14	

a. Condition = SOF, Point = V

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	6,000	8,501	6,000
df	2	2	2
Asymp. Sig.	,050	,014	,050

a. Condition = SOF, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = SOF, Point = C7

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	5,57
	R	5	9,40
	DCD	2	9,50
	Total	14	
Amplitude_AP	T	7	5,43
	R	5	9,20
	DCD	2	10,50
	Total	14	
Mean_Velocity_AP	T	7	5,57
	R	5	9,40
	DCD	2	9,50

	Total	14	

a. Condition = SOF, Point = C7

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	2,976	3,571	2,976
df	2	2	2
Asymp. Sig.	,226	,168	,226

a. Condition = SOF, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = VF, Point = V

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	6,29
	R	5	8,80
	DCD	2	8,50
	Total	14	
Amplitude_AP	T	7	6,14
	R	5	9,00
	DCD	2	8,50
	Total	14	
Mean_Velocity_AP	T	7	6,29
	R	5	8,80
	DCD	2	8,50
	Total	14	

a. Condition = VF, Point = V

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	1,187	1,494	1,187
df	2	2	2
Asymp. Sig.	,552	,474	,552

a. Condition = VF, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = VF, Point = C7

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	5,86
	R	5	9,20
	DCD	2	9,00
	Total	14	
Amplitude_AP	T	7	5,71
	R	5	8,60
	DCD	2	11,00
	Total	14	
Mean_Velocity_AP	T	7	5,86
	R	5	9,20
	DCD	2	9,00
	Total	14	

a. Condition = VF, Point = C7

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	2,162	3,021	2,162
df	2	2	2
Asymp. Sig.	,339	,221	,339

a. Condition = VF, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = FOA, Point = V

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	7,29
	R	5	8,60
	DCD	2	5,50
	Total	14	
Amplitude_AP	T	7	7,57
	R	5	8,80
	DCD	2	4,00
	Total	14	
Mean_Velocity_AP	T	7	7,29
	R	5	8,60
	DCD	2	5,50

	Total	14	

a. Condition = FOA, Point = V

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	,821	1,885	,821
df	2	2	2
Asymp. Sig.	,663	,390	,663

a. Condition = FOA, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = FOA, Point = C7

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	7,29
	R	5	7,60
	DCD	2	8,00
	Total	14	
Amplitude_AP	T	7	6,71
	R	5	8,20
	DCD	2	8,50
	Total	14	
Mean_Velocity_AP	T	7	7,29
	R	5	7,60
	DCD	2	8,00
	Total	14	

a. Condition = FOA, Point = C7

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	,050	,501	,050
df	2	2	2
Asymp. Sig.	,975	,778	,975

a. Condition = FOA, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = FOF, Point = V

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	6,57
	R	5	10,00
	DCD	2	4,50
	Total	14	
Amplitude_AP	T	7	6,43
	R	5	10,20
	DCD	2	4,50
	Total	14	
Mean_Velocity_AP	T	7	6,57
	R	5	10,00
	DCD	2	4,50
	Total	14	

a. Condition = FOF, Point = V

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	3,159	3,571	3,159
df	2	2	2
Asymp. Sig.	,206	,168	,206

a. Condition = FOF, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: Group

Condition = FOF, Point = C7

Ranks[a]

	Group	N	Mean Rank
Total_Distance_AP	T	7	5,57
	R	5	9,80
	DCD	2	8,50
	Total	14	
Amplitude_AP	T	7	4,43
	R	5	10,60
	DCD	2	10,50
	Total	14	
Mean_Velocity_AP	T	7	5,57
	R	5	9,80
	DCD	2	8,50

Total	14	

a. Condition = FOF, Point = C7

Test Statistics[a,b,c]

	Total_Distance_AP	Amplitude_AP	Mean_Velocity_AP
Chi-Square	3,113	7,548	3,113
df	2	2	2
Asymp. Sig.	,211	,023	,211

a. Condition = FOF, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: Group

NPar Tests
Kruskal-Wallis Test – Nonlinear data

Condition = SOA, Point = V

Ranks[a]

	DCD	N	Mean Rank
Rec	Tipico	7	7,71
	Risco	5	8,40
	DCD	2	4,50
	Total	14	
Det	Tipico	7	7,71
	Risco	5	9,40
	DCD	2	2,00
	Total	14	
Meanline	Tipico	7	7,57
	Risco	5	9,20
	DCD	2	3,00
	Total	14	
Maxline	Tipico	7	5,50
	Risco	5	8,50
	DCD	2	12,00
	Total	14	
Entropy	Tipico	7	7,43
	Risco	5	9,00
	DCD	2	4,00
	Total	14	
Laminarity	Tipico	7	7,71
	Risco	5	9,20
	DCD	2	2,50

	Total	14	
Vmax	Tipico	7	7,86
	Risco	5	8,60
	DCD	2	3,50
	Total	14	
SampleEntropy	Tipico	7	9,14
	Risco	5	5,40
	DCD	2	7,00
	Total	14	
Lyapunov	Tipico	7	6,71
	Risco	5	7,20
	DCD	2	11,00
	Total	14	

a. Condition = SOA, Point = V

Test Statistics^{a,b,c}

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	1,278	4,507	3,142	4,228	2,045	3,701	2,225	2,389	1,673
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,528	,105	,208	,121	,360	,157	,329	,303	,433

a. Condition = SOA, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = SOA, Point = C7

Ranks^{a}

	DCD	N	Mean Rank
Rec	Tipico	7	8,00
	Risco	5	8,40
	DCD	2	3,50
	Total	14	
Det	Tipico	7	7,57
	Risco	5	9,40
	DCD	2	2,50
	Total	14	
Meanline	Tipico	7	7,57
	Risco	5	9,00
	DCD	2	3,50
	Total	14	

Maxline	Tipico	7	8,57
	Risco	5	6,60
	DCD	2	6,00
	Total	14	
Entropy	Tipico	7	7,43
	Risco	5	8,80
	DCD	2	4,50
	Total	14	
Laminarity	Tipico	7	7,71
	Risco	5	9,40
	DCD	2	2,00
	Total	14	
Vmax	Tipico	7	7,79
	Risco	5	8,10
	DCD	2	5,00
	Total	14	
SampleEntropy	Tipico	7	9,57
	Risco	5	5,40
	DCD	2	5,50
	Total	14	
Lyapunov	Tipico	7	8,57
	Risco	5	6,60
	DCD	2	6,00
	Total	14	

a. Condition = SOA, Point = C7

Test Statistics^{a,b,c}

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	2,160	3,891	2,473	,954	1,513	4,507	,852	3,433	,948
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,340	,143	,290	,621	,469	,105	,653	,180	,623

a. Condition = SOA, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = SOF, Point = V

Ranks^{a}

	DCD	N	Mean Rank
Rec	Tipico	7	7,43
	Risco	5	7,20
	DCD	2	8,50

	Total	14	
Det	Tipico	7	9,57
	Risco	5	6,40
	DCD	2	3,00
	Total	14	
Meanline	Tipico	7	8,29
	Risco	5	6,80
	DCD	2	6,50
	Total	14	
Maxline	Tipico	7	6,07
	Risco	5	9,00
	DCD	2	8,75
	Total	14	
Entropy	Tipico	7	9,57
	Risco	5	6,60
	DCD	2	2,50
	Total	14	
Laminarity	Tipico	7	8,57
	Risco	5	7,40
	DCD	2	4,00
	Total	14	
Vmax	Tipico	7	7,43
	Risco	5	7,60
	DCD	2	7,50
	Total	14	
SampleEntropy	Tipico	7	9,57
	Risco	5	4,60
	DCD	2	7,50
	Total	14	
Lyapunov	Tipico	7	6,57
	Risco	5	8,00
	DCD	2	9,50
	Total	14	

a. Condition = SOF, Point = V

Test Statistics^{a,b,c}

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	,142	4,376	,501	1,641	4,805	1,862	,005	4,128	,873
df	2	2	2	2	2	2	2	2	2

Asymp. Sig.	,931	,112	,778	,440	,090	,394	,998	,127	,646

a. Condition = SOF, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = SOF, Point = C7

Ranks[a]

	DCD	N	Mean Rank
Rec	Tipico	7	7,29
	Risco	5	7,60
	DCD	2	8,00
	Total	14	
Det	Tipico	7	7,29
	Risco	5	8,80
	DCD	2	5,00
	Total	14	
Meanline	Tipico	7	7,86
	Risco	5	8,40
	DCD	2	4,00
	Total	14	
Maxline	Tipico	7	6,07
	Risco	5	8,70
	DCD	2	9,50
	Total	14	
Entropy	Tipico	7	8,00
	Risco	5	8,20
	DCD	2	4,00
	Total	14	
Laminarity	Tipico	7	7,71
	Risco	5	8,00
	DCD	2	5,50
	Total	14	
Vmax	Tipico	7	8,29
	Risco	5	8,60
	DCD	2	2,00
	Total	14	
SampleEntropy	Tipico	7	8,86
	Risco	5	4,40

	DCD	2	10,50
	Total	14	
Lyapunov	Tipico	7	8,00
	Risco	5	5,60
	DCD	2	10,50
	Total	14	

a. Condition = SOF, Point = C7

Test Statistics[a,b,c]

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	,050	1,216	1,682	1,689	1,640	,547	4,050	4,521	2,160
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,975	,545	,431	,430	,440	,761	,132	,104	,340

a. Condition = SOF, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = V, Point = V

Ranks[a]

	DCD	N	Mean Rank
Rec	Tipico	7	7,29
	Risco	5	8,40
	DCD	2	6,00
	Total	14	
Det	Tipico	7	8,71
	Risco	5	6,60
	DCD	2	5,50
	Total	14	
Meanline	Tipico	7	8,71
	Risco	5	6,40
	DCD	2	6,00
	Total	14	
Maxline	Tipico	7	6,36
	Risco	5	8,50
	DCD	2	9,00
	Total	14	
Entropy	Tipico	7	9,00
	Risco	5	6,40
	DCD	2	5,00
	Total	14	

Laminarity	Tipico	7	8,71
	Risco	5	6,20
	DCD	2	6,50
	Total	14	
Vmax	Tipico	7	6,14
	Risco	5	7,60
	DCD	2	12,00
	Total	14	
SampleEntropy	Tipico	7	7,86
	Risco	5	7,00
	DCD	2	7,50
	Total	14	
Lyapunov	Tipico	7	7,43
	Risco	5	7,60
	DCD	2	7,50
	Total	14	

a. Condition = V, Point = V

Test Statistics^{a,b,c}

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	,507	1,278	1,193	1,082	1,960	1,187	3,054	,124	,005
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,776	,528	,551	,582	,375	,552	,217	,940	,998

a. Condition = V, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = V, Point = C7

Ranks^{a}

	DCD	N	Mean Rank
Rec	Tipico	7	7,29
	Risco	5	8,80
	DCD	2	5,00
	Total	14	
Det	Tipico	7	7,14
	Risco	5	9,00
	DCD	2	5,00
	Total	14	
Meanline	Tipico	7	7,29

	Risco	5	7,00
	DCD	2	9,50
	Total	14	
Maxline	Tipico	7	7,43
	Risco	5	9,60
	DCD	2	2,50
	Total	14	
Entropy	Tipico	7	8,29
	Risco	5	7,20
	DCD	2	5,50
	Total	14	
Laminarity	Tipico	7	7,14
	Risco	5	8,20
	DCD	2	7,00
	Total	14	
Vmax	Tipico	7	8,14
	Risco	5	6,00
	DCD	2	9,00
	Total	14	
SampleEntropy	Tipico	7	9,00
	Risco	5	5,40
	DCD	2	7,50
	Total	14	
Lyapunov	Tipico	7	7,57
	Risco	5	8,00
	DCD	2	6,00
	Total	14	

a. Condition = V, Point = C7

Test Statistics[a,b,c]

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	1,216	1,408	,547	4,165	,730	,220	1,065	2,179	,331
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,545	,495	,761	,125	,694	,896	,587	,336	,848

a. Condition = V, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = FOA, Point = V

Ranks[a]

	DCD	N	Mean Rank
Rec	Tipico	7	7,43
	Risco	5	10,00
	DCD	2	1,50
	Total	14	
Det	Tipico	7	8,29
	Risco	5	8,60
	DCD	2	2,00
	Total	14	
Meanline	Tipico	7	8,00
	Risco	5	9,20
	DCD	2	1,50
	Total	14	
Maxline	Tipico	7	8,50
	Risco	5	8,10
	DCD	2	2,50
	Total	14	
Entropy	Tipico	7	8,00
	Risco	5	9,20
	DCD	2	1,50
	Total	14	
Laminarity	Tipico	7	7,71
	Risco	5	9,20
	DCD	2	2,50
	Total	14	
Vmax	Tipico	7	7,71
	Risco	5	9,20
	DCD	2	2,50
	Total	14	
SampleEntropy	Tipico	7	7,86
	Risco	5	6,00
	DCD	2	10,00
	Total	14	
Lyapunov	Tipico	7	7,43
	Risco	5	7,80
	DCD	2	7,00
	Total	14	

a. Condition = FOA, Point = V

Test Statistics[a,b,c]

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	5,902	4,050	5,040	3,397	5,040	3,701	3,701	1,727	,056
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,052	,132	,080	,183	,080	,157	,157	,422	,972

a. Condition = FOA, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = FOA, Point = C7

Ranks[a]

	DCD	N	Mean Rank
Rec	Tipico	7	6,86
	Risco	5	8,00
	DCD	2	8,50
	Total	14	
Det	Tipico	7	7,00
	Risco	5	8,40
	DCD	2	7,00
	Total	14	
Meanline	Tipico	7	7,71
	Risco	5	7,60
	DCD	2	6,50
	Total	14	
Maxline	Tipico	7	7,21
	Risco	5	7,90
	DCD	2	7,50
	Total	14	
Entropy	Tipico	7	7,29
	Risco	5	8,20
	DCD	2	6,50
	Total	14	
Laminarity	Tipico	7	7,00
	Risco	5	8,40
	DCD	2	7,00
	Total	14	
Vmax	Tipico	7	7,71
	Risco	5	7,20
	DCD	2	7,50
	Total	14	

SampleEntropy	Tipico	7	7,43
	Risco	5	8,40
	DCD	2	5,50
	Total	14	
Lyapunov	Tipico	7	8,00
	Risco	5	6,80
	DCD	2	7,50
	Total	14	

a. Condition = FOA, Point = C7

Test Statistics[a,b,c]

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	,351	,360	,136	,079	,273	,360	,044	,691	,240
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,839	,835	,934	,961	,873	,835	,978	,708	,887

a. Condition = FOA, Point = C7

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = FOF, Point = V

Ranks[a]

	DCD	N	Mean Rank
Rec	Tipico	7	6,71
	Risco	5	9,40
	DCD	2	5,50
	Total	14	
Det	Tipico	7	8,29
	Risco	5	8,80
	DCD	2	1,50
	Total	14	
Meanline	Tipico	7	8,43
	Risco	5	8,00
	DCD	2	3,00
	Total	14	
Maxline	Tipico	7	7,64
	Risco	5	7,80
	DCD	2	6,25
	Total	14	
Entropy	Tipico	7	8,14

	Risco	5	8,60
	DCD	2	2,50
	Total	14	
Laminarity	Tipico	7	8,57
	Risco	5	8,00
	DCD	2	2,50
	Total	14	
Vmax	Tipico	7	7,57
	Risco	5	8,60
	DCD	2	4,50
	Total	14	
SampleEntropy	Tipico	7	8,14
	Risco	5	5,20
	DCD	2	11,00
	Total	14	
Lyapunov	Tipico	7	6,14
	Risco	5	7,80
	DCD	2	11,50
	Total	14	

a. Condition = FOF, Point = V

Test Statistics[a,b,c]

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	1,736	4,844	2,731	,217	3,368	3,388	1,376	3,104	2,591
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,420	,089	,255	,897	,186	,184	,502	,212	,274

a. Condition = FOF, Point = V

b. Kruskal Wallis Test

c. Grouping Variable: DCD

Condition = FOF, Point = C7

Ranks[a]

	DCD	N	Mean Rank
Rec	Tipico	7	6,57
	Risco	5	8,80
	DCD	2	7,50
	Total	14	
Det	Tipico	7	7,43
	Risco	5	10,00

	DCD	2	1,50
	Total	14	
Meanline	Tipico	7	6,71
	Risco	5	10,80
	DCD	2	2,00
	Total	14	
Maxline	Tipico	7	8,93
	Risco	5	5,80
	DCD	2	6,75
	Total	14	
Entropy	Tipico	7	7,43
	Risco	5	10,00
	DCD	2	1,50
	Total	14	
Laminarity	Tipico	7	8,29
	Risco	5	8,80
	DCD	2	1,50
	Total	14	
Vmax	Tipico	7	6,36
	Risco	5	10,40
	DCD	2	4,25
	Total	14	
SampleEntropy	Tipico	7	9,71
	Risco	5	3,60
	DCD	2	9,50
	Total	14	
Lyapunov	Tipico	7	7,71
	Risco	5	5,40
	DCD	2	12,00
	Total	14	

a. Condition = FOF, Point = C7

Test Statistics^{a,b,c}

	Rec	Det	Meanline	Maxline	Entropy	Laminarity	Vmax	SampleEntropy	Lyapunov
Chi-Square	,828	5,902	6,816	1,733	5,902	4,844	4,142	6,764	3,593
df	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,661	,052	,033	,420	,052	,089	,126	,034	,166

a. Condition = FOF, Point = C7 b. Kruskal Wallis Test c. Grouping Variable: DCD