UNIVERSITÀ DEGLI STUDI DI TRIESTE

XXXI CICLO DEL DOTTORATO DI RICERCA IN NEUROSCIENZE E SCIENZE COGNITIVE

THE MOTOR DIFFICULTIES IN THE SPORTY TYPICALLY DEVELOPING CHILDREN: A MULTIDISCIPLINARY APPROACH

Settore Scientifico-Disciplinare: M-PSI/04

DOTTORANDA
FRANCESCA POLICASTRO

COORDINATORE
PROF. TIZIANO AGOSTINI

SUPERVISORE DI TESI
PROF. AGOSTINO ACCARDO

ANNO ACCADEMICO 2017/2018

INDEX

1. PREFACE

Nowadays children and adolescents are involved in many activities during their young life. The actual society gives different possibilities to practice physical activity or sport. They could choose competitive sports or general motor activities. Coaches, educators, and teachers propose to the young people to play and move. Anyway the children sometimes face complex movements, difficult gestures and tasks, for which they are not ready. Specific sport practice requires many physical, cognitive, and behavioural skills. If the children don't manage properly these skills, they could have difficulties to afford the task. This research project investigates the factors, which play a role in the motor development. In collaboration with some schools and Basketball Clubs of Trieste (Italy), the aim was to provide a multidisciplinary assessment of the children aged between 7 and 12 years, who are practicing basketball. In order to identify the different aspects, which impact on the development of typically developing and active children, this research evaluate structural, cognitive and motor factors. A deeper understanding of these aspects should bring more consciousness about the correct activity to choose, different for each child.

The present research project comes from my personal interest to examine the motor development of the children. As physiotherapist and basketball coach I would understand how to help the children to improve their motor skills. I would also verify, which factors could impact their motor development, like for example the posture, the cognitive abilities, weight, and height. In this work, I didn't consider children with diagnose of motor disorders or developmental disorders. I decided to focus my interest on healthy, but sometimes clumsy children, who can move in an awkward way, but who practice a sport activity indeed, in particular, basketball. This research project develops in different sections, which take into account more details about the motor development of the children. I have considered the posture, the cognitive abilities, the kinematic profile, weight, and height because all these aspects impact on children's movement and behaviour.

Because of my background as a physiotherapist, the project begins by understanding the posture of the children who play basketball. This sport practice is considered as a risk factor to develop Low Back Pain for adolescents. This confirms that the basketball practice has an impact on the way the children move, and on their posture too. In a longitudinal study of almost 2 years, I have assessed the posture of young basketball players. With a precise prevention protocol, I tried to have an impact on their posture. Through this protocol, I would propose different exercises to offer them the possibility to move in a different way. I tried to influence the muscles strengths, the balance, and the ability to stretch the body. The aims were: to verify whether the postural modification was possible and to verify whether postural modifications could lead to movement modifications, and could be useful to prevent injuries. I also monitored the emerging of Low Back Pain and other injuries. In this part of the project, I also assessed height and weight of the sample. According to the literature, these physical aspects have an impact on the posture, and on children's movement abilities.

The second section of this project refers to the cognitive aspects, involved in the motor development of this particular sample. I assessed young basketball players of different teams for cognitive abilities like attention (in terms of denomination, inhibition, and switching), visuo-spatial working memory, and imitation of motor manual sequences. I also evaluated them for manual dexterity, balance, aiming and catching skills. The aim of this work was to verify which correlations between cognitive and motor functions exist in this particular sample. The relevance of this part of the study was large. The tests could demonstrate the level of ability in the different tasks; they probably could establish which activities improve to reduce –or at least modify- clumsiness or motor difficulties. Moreover, these outcomes permit to identify the cognitive skills related to motor abilities. Through this evidence coaches and trainers could identify which functions to propose in order to be more incisive on the development of the sample, as children and players.

I finally assessed the kinematic of a vertical jump of these children. Through a validated system of accelerometers, I tried to enrich the literature about the ability to jump – for children. By considering also some particular case, I tried to find out whether correlations between the ability to jump and cognitive aspects exist. Even if this part of the study consists of different qualitative considerations, it was very important to complete the assessment of the children. The biggest aim of the complete project was to understand all the factors that could impact on the movement abilities of children, who are clumsy and awkward but not – at least apparently - affected by developmental disorders. The deep assessment of these young healthy and sporty children suggests us that the intervention to improve their motor abilities must be multidimensional.

Finally, I understood that the other possibility to help the children in their movement difficulties is to intervene before the motor difficulties appear. For this reason, the last part of this project consists in a prevention program to promote physical activity for pre-schooler children, who are not already practising a sport. In collaboration with other colleagues, we translated and adapted the Australian "Animal Fun" movements program for the Italian children. An Australian team of researchers introduced this program to promote the physical activity during the school schedule. This program is funny and interactive and involved the animals' movement and gestures. The aim of our translation and adaptation was to verify which impact this proposal could have on young Italian children and to understand whether this activity could help them to improve some motor abilities, like balance or aiming and catching.

In the present social context, in which the technology and the sedentary activity have taken large place, could be important to introduce the motor education as soon as possible, and to guarantee that all the factors which impact on, would be considered.

2. THE MOTOR DIFFICULTIES AND THE THEORY OF CONSTRAINTS

Each prevention or therapeutic program comes from a previous detailed analysis of the considered problem. In this study, I am addressing developmental motor difficulties in the young population. Especially because of the peculiarities of this sample, since the beginning, I have considered all the factors, which could impact on the motor development.

From 1986, Newell[1] describes the three necessary constraints to action: the environment, the organism, and the task. These factors limit, contain, and help shape the motor development. In according to the previous principles of the coordinative structure theory, the sources of constraint to action permit the observable motor behaviour. Figure 1 schematically shows this framework.

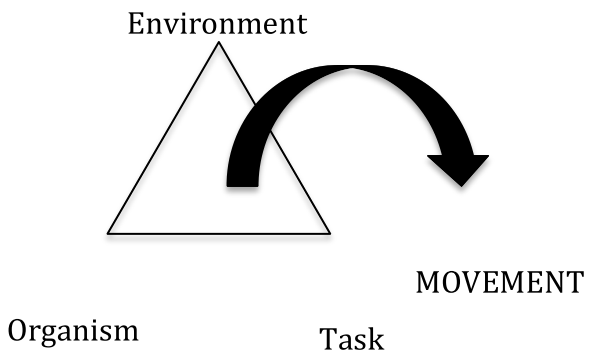


Figure 1. Newell's Constraints Theory

The individual constraints are located inside the body and are structural (i.e. height, weight) and functional (i.e. motivation, anxiety). The environmental constraints are located outside the body and could be concrete (i.e. the surface, the gravity) or more abstract (i.e. gender role, cultural norms). The task constraints are also located outside the body and refer to the characteristics of a specific task or skill (i.e. the goal of the task, the rules, the equipment)[2]. Through his theory, Newell creates a bridge in the perceived gap between motor control and learning principles, and the between the biological and the behavioural level of analysis (Anson, 2015[3]).

Newell creates a dynamic systems conceptual framework, where the constraints are considered from both the internal and the external perspective. The constraints have an interactive nature to channel the action dynamics. This means that they have an explicit and implicit influence on actions. The three factors impact on each other; the result is the action. This theory gives a bottom-up perspective to consider the motor action. Newell suggests to fully exploring the ontology of the movement, taking into account this dynamic systems model.[4] Anson[3] supports that Newell introduced the constraints framework to understand the coordination and the control in the motor development. This perspective should be useful to examine coordination "as a general theoretical problem independent of activity class and developmental stage", and to find out perspectives about the orientation of motor development and coordinative structures. In his view, the coordination is an emerging pattern, created by the interaction of the three constraints. Once the coordination is integrated and available, the subject has to learn how to control it.

In the present project, I decided to consider the Newell's constraints theory as a starting point to plan the assessment of the children. This theoretical framework especially supports the individual structural constraints; in the following chapters I am going to provide other perspectives, which deeply support the cognitive influence on the motor development[5 6]. My purpose was to identify which could be the aspects, which lead a child to move differently respect the others. I aimed to examine different impacting factors, which could help the children to modify its motor habits. I concentrated more on the individual constraints, which participate in the development of the motor abilities. Taking into account the environment constraints, the present research focuses on the basketball practice. In the following chapters, all the assessments are described. Anyway, I first took into account the postural situation of the subjects, and I considered how the Body Mass Index (BMI) could influence the posture. BMI and posture are physical individual constraints, which impact on the ability of the child to move, and on its possibility to prevent injuries. In the second part of the project, I assessed how the children develop cognitive abilities like visuospatial working memory, attention, motor memory in relation to manual dexterity, balance and aiming and catching abilities. These skills are all functional individual constraints, located inside the body. The last part of the evaluations consisted in the kinematic assessment of the vertical jump. This movement requires specific functional and physical individual characteristics to be well done. I asked the children for a gesture they well known because of practising basketball; by considering also the task constraint, I tried to facilitate the children. Referring to the environmental constraint, I proposed the evaluations in a confident and calm place of the gym, where the children play basketball and normally enjoy. Individual, task and environment constraints also depend on the basketball practice, a common aspect or all the assessed children.

Newell's theory is not the only theoretical framework I referred. I considered also the Hands and Larkin's (2002)[7 8 9] negative feedback loop. The authors make explicit the correlations between the motor coordination and other outcomes, such as the obesity. Considering motor coordination, hypo-activity and physical fitness, they suggest that the deterioration in one domain can cause deterioration in another domain. This negative influence becomes a negative loop, which continuously declines. Hands and Larkin also consider the importance of individual and environmental variables. Figure 2 shows the schema of this loop.

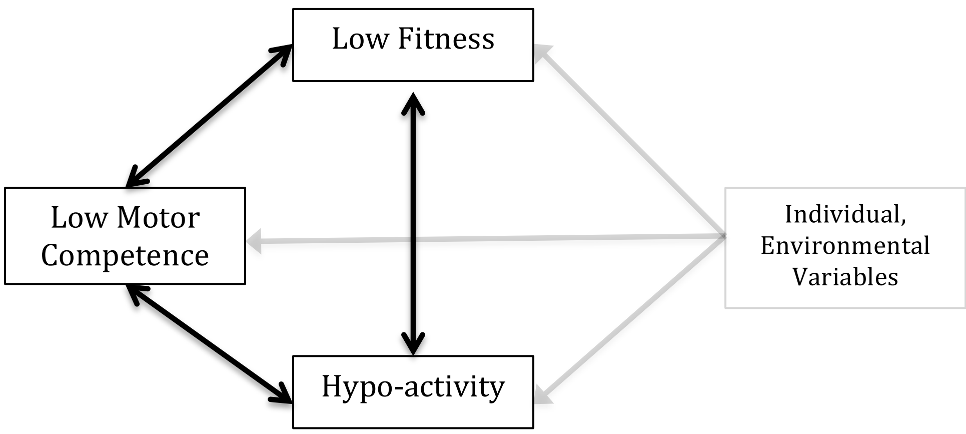


Figure 2: Hands and Larkin's continuous negative feedback loop.

In my study, I took into account this theory because all the examined variables fit in the schema described by Hands and Larkin. In fact, my starting hypothesis was to find out strict correlations between all the variables I assessed.

BIBLIOGRAPHY

[1] Newell, K. M., Van Emmerik, R. E. A., & McDonald, P. V. (1989). Biomechanical constraints and action theory. *Human Movement Science*, *8*, 403-409.

[2] McGinnis, P. M., & Newell, K. M. (1982). Topological dynamics: A framework for describing movement and its constraints. *Human Movement Science*, *1*(4), 289-305.

[3] Anson, G., Elliott, D., & Davids, K. (2005). Information processing and constraints-based views of skill acquisition: divergent or complementary?. *Motor control*, *9*(3), 217-241.

[4] Newell, K. M. (1991). Motor skill acquisition. *Annual review of psychology*, *42*(1), 213-237.

[5] Coker, C. A. (2017). *Motor learning and control for practitioners*. Routledge.

[6] Rosenbaum, D. A. (2009). *Human motor control*. Academic press.

[7] Hands, B.P., Parker, H., & Larkin, D. (2002). What do we really know about the constraints and enablers of physical activity levels in young children?.

[8] Cairney, J., & Veldhuizen, S. (2013). Is developmental coordination disorder a fundamental cause of inactivity and poor health-related fitness in children?. *Developmental Medicine & Child Neurology*, *55*, 55-58.

[9] Cairney, J. (Ed.). (2015). *Developmental coordination disorder and its consequences*. University of Toronto Press.

3. THE POSTURAL IMPACT ON THE PREVENTION OF INJURIES: A LONGITUDINAL STUDY

Because of my personal background as a physiotherapist, this work has been the starting point of the complete project. In this part, I considered, by intervening on their posture, the possibility to modify the motor behaviour of the children. My outcome measure was the prevention of the Low Back Pain during two years of basketball practice. By the Newell's theory[1], the posture is a physical individual constraint, which participates in the creation of the movement.

INTRODUCTION

The posture is worldwide considered like the way our body faces the external stimuli like gravity or instability. Furthermore, it influences our ability to move and our way to behave. By influencing the motor skills this is also a necessary aspect to consider preventing injuries, like the Low Back Pain (LBP). This is a common muscle-skeletal disorder, which also impacts on children and adolescents. Watson (2002)[2] affirms that the incidence of LBP is similar in adolescents and adults. In the scholar population, the prevalence is age-related, in particular, it doubles from 12 until 15 years of age. Calvo-Muñoz and colleagues (2013)[3] confirm that 61.7% is the prevalence of LBP in the under18 population. The presence of LBP in the young population is completely linked to the presence of the risk factors. Hill and colleagues (2010)[4] found out 47 risk factors for LBP. Anyway, the author affirms that is rarely possible to identify a clear correlation between risk factors and LBP.

Evidence about the correlation between LBP and risk factors in the young population is a little; furthermore, sometimes there are controversial outcomes, because of a lack of follow-up research. Nevertheless, European Guidelines (2006)[5] suggest that LBP depends on lifestyle-related, school-related, psychosocial-related, and physical-related risk factors, i.e. obesity and sedentariness. Cairney[9] affirms that hypo-activity is involved in a continuous negative feedback loop in relation to motor coordination and physical fitness. Referring to Hands and colleagues (2002)[6] and Wall's (2004)[7] theories, Cairney demonstrates that obesity and overweight can lead to inactivity and sedentariness[8]. Inactivity itself can lead to poor coordination and poor fitness, which mean to have, for instance, children with tight and inflexible muscles, or with poor aerobic training. All these relations are bidirectional and influence on each other. All the conditions are a risky factor to develop disorders or injuries, like juvenile LBP. It could seem controversial, but the European Guidelines (2006) also affirm that the sport practice doesn't clearly protect the young population from the LBP. In fact, in their review, Balagué, Troussier and Salminen (1999)[9] report a lot of studies, where a correlation between the incidence of LBP and intense competitive sport practice emerges. For instance, Taimel[10] and colleagues found out this correlation in a sample of 1171 children aged between 7 and 16 years old. Balagué and colleagues[9] found out the same result in a sample of 1700 children, aged between 8 and 16 years old. The review identifies in particular basketball, volleyball, and soccer -but practised at a competitive level- as a risky activity. Skoffer and colleagues (2008)[11] evaluated 546 adolescents 15-16-years-old. The practice of impact team-sport influences the prevalence of LBP. I can assume that the literature is controversial on this topic, but it is clear that physical activity is necessary, if appropriate and well managed for the children. Probably the competitive team-sport practice has a strong impact on the body of the children, on their posture, and on their way to move. Fett and colleagues (2017)[12] demonstrated that the LBP prevalence increases in young athletes who practice sport at a competitive level. The European Guidelines also highlight the impact of physical factors, as risk factors. The evidence is a few also for this topic, but Feldman and colleagues (2001)[13] affirm that muscles tightness (in particular of hamstrings) and reduced trunk strength and stability are risk factors for LBP, both in adults and adolescents. Cardon and Balgue (2004)[14], and Burton and colleagues (2014)[5] also support this assertion.

In this study, I propose an LBP prevention protocol for pre-adolescents and adolescents who are practising basketball at a competitive level. I propose training for specific abilities, those should permit the children to improve their posture, their way to move and to prevent LBP. I aim to have an impact on some risk factor to improve the way the children move. To verify my aim I use photogrammetric software to assess the posture of the sample. The modification of the posture could lead to a better ability to move, to a better body balance (in terms of muscles length and strength), both necessary to prevent LBP.

MATERIALS AND METHODS

The Ethics Committee of the University of Trieste approved this study. All the parents of the children read and signed the written informed consent.

This is a longitudinal study, which considers the same population between September 2016, and June 2018 (two basketball seasons). The players were recruited in a basketball Club of Trieste (Pallacanestro Interclub Muggia). In this club, the young players afford 3 trainings a week and already play the games versus other Clubs. They play basketball at a competitive, intense level.

The study develops in different stages.

Stage 1 - first photogrammetric assessment on September 2016

Stage 2 - proposal of weekly prevention protocol for LBP and common injuries. They practice this protocol with a physiotherapist for 30 minutes, during the basketball training.

Stage 3 – second photogrammetric assessment during summer 2017

Stage 4 – same proposal of the prevention protocol

Stage 5 – last photogrammetric assessment on June 2018.

The players were monitored for their physical health, by constantly asking them about injuries or accidents.

The informed written consent, and participating in the training 3 times a week were inclusion criteria.

Acute or chronic LBP is an exclusion criterion because the study aims to prevent it. Other acute injuries excluded the participants if they were not able to afford the first assessment.

For the ethical reason, the sample is not randomized because I proposed the protocol to the entire team.

<u>Referring measurements</u>

I refer to literature to verify the postural situation of the sample. The considered measures are the Cranio-Cervical Angle (CCA), the Lumbar-Pelvic Angle (LPA), the Tibio-Tarsal Angle (TTA), the Curved Knee Angle (CKA), the Varus/Valgus knee Angle (VVA), the Arch Index (AI), the Forward Bending Index (FBI).

- The CCA is composed by the intersection between the horizontal line which passes through C7, and the intersection line which touches C7 and the tragus. 51.25° is the cut-off value to discriminate a physiological head position or a forward head (<51.25°)[15].
- The LPA is considered in forward bending. It is composed by the intersection between the line, which touches the anterior-superior iliac spine and the posterior-superior iliac spine, and the line, which touches the great trochanter and the articular line of the knee. Whether the angle is < 12.6° the hamstrings are considered elastic. The angle included between 12.6° and 22.5° refers to a normal elasticity of the hamstrings. The angle > 22.5° defines stiff hamstrings. This is an important value to consider in the incidence of LBP[16].
- The TTA is considered in forward bending. It is composed by the horizontal line, which touches the lateral malleolus and the line, which passes through the articular line of the knee and the lateral malleolus. The TTA >90° determines stiffness in hamstrings and ankle.[17]
- The CKA is the angle between the line, which touches the great trochanter, and the articular line of the knee, and the line, which touches the articular line of the knee and the lateral malleolus[18]. The cut-off value is 185°[19].
- The VVA is composed by the intersection of the line, which passes through the anterior-superior iliac spine and the medium point of the patella, and the line, which passes through the medium point of the patella and the lateral malleolus. The cut-off value to consider a valgus knee is 174.5°[20].
- The AI comes from the relation between the length and the height of the plantar arch. The AI>6.74 defines a flat foot[21].
- The FBI id the distance between the finger and the sole during a forward bending. It is correlated to the elasticity of the hamstrings. The cut-off value is 15cm[22].

Population

38 children (25 males, 13 females), mean age=11.68 (SD=1.51) from the same basketball Club were recruited. They were born between 2004 and 2008, and they practiced basketball three times for a week, at a competitive level.

Procedure

I propose an anamnestic questionnaire and a photogrammetric assessment through the validated digital system of postural analysis SAPO (Ferreira, 2010)[23]. The existing literature supports this kind of assessment, which demonstrates satisfying level of reliability[24 25]. I put markers an the following point: tragi, spinal process of C7, T3, T7, L1, L3, L5, anterior-superior iliac spines, posterior-superior iliac spines, femurs (greater trochanter), knees (articular line), patellae (medium point), legs (point a medial line), calcaneal tendon between malleolus, and malleoli. To mark the points I positioned styrofoam balls (15 cm circumference) using double-faced adhesive tape. The camera (Nikon Coolpix L100) was placed on tripods (height of 1.50) with an angle of 90 degrees (same distance). The camera was placed 2 meters from the subject. A plumb line marked with two styrofoam balls was used for vertical calibration. I took 8 pictures for each subject: anterior frontal standing, posterior frontal standing, left-side sagittal standing, right-side sagittal standing, right-side sagittal forward bending, posterior frontal view of the feet, left-side sagittal view of one foot, right-side sagittal view of the other foot. In all the assessing stages I took the same number of pictures. I used a reserved calm place of the gym during the basketball training. Then, I analyzed the pictures through the software SAPO v0.68 in the Physiotherapy University of Trieste.

I complete the statistical analysis through the software MatLab®.

Treatment protocol

To create the prevention protocol, I took into account the first assessments I did. Considered as physical risk factors for LBP, I decided to aim to modify the following variables: the hamstrings elasticity, the angles of the knee, and the stiffness of the whole back. I also included important aspects of core-stability to intervene on the way the children use their body and their posture to move and play.

The protocol consists in:

- global active stretching (on the wall or in forward bending, closing LPA, 5');
- selective stretching (rectus femoris, psoas, adductors, 1' each);
- one/two-legs bridge exercise (20 repetitions each);
- horizontal and lateral plank (2 times for 20");
- medium gluteus, abductors side exercises (20 repetitions each)
- one-foot-standing with/without dynamic movements, and open/closed eyes (1' each exercise, in a total of 5/6');
- split squat, side squat, wall sit (2 times for 20" each);
- feet rapidity exercises (2' each).

The prevention protocol was proposed for 30' one time a week, before the children begun the basketball training. I proposed the same exercises in both basketball seasons. The protocol had been produced and proposed by a physical therapist, which assisted, corrected and helped the children. In all the activity the physical therapist remembered to the children to pay attention at the position of their knees, of their backs, and of their feet.

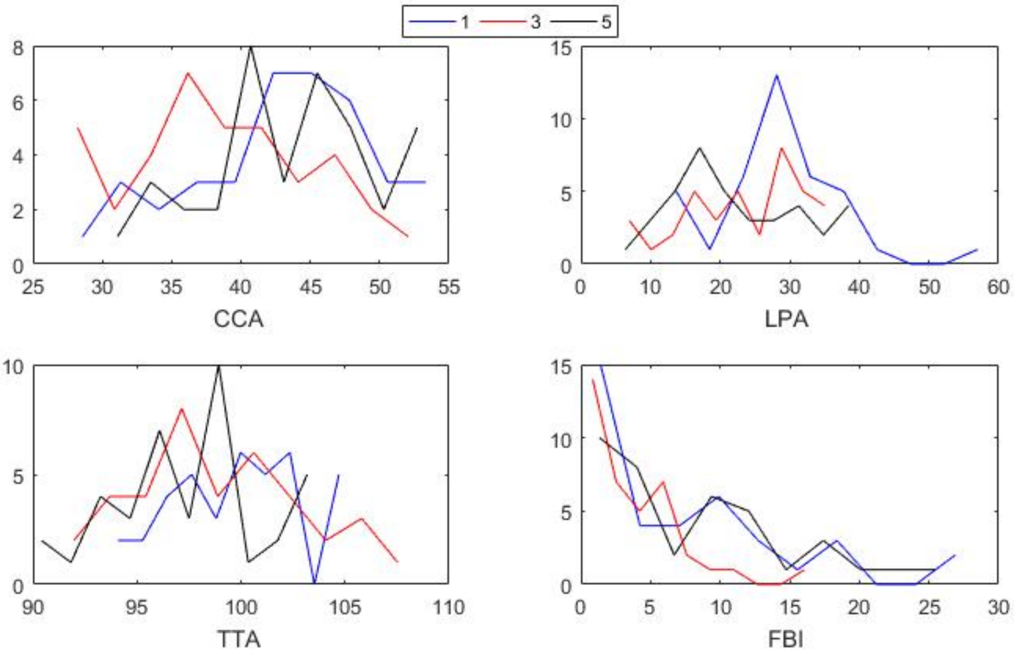
Limitations

The small number of participants, not having a control group, and not continuing the protocol during the summer holidays, are all limits of this study. Nevertheless, these aspects are all due to the organization of the proposal, which involved just one basketball Club. I am working to solve these problems in the immediate future.

RESULTS

The following Figures 1 and 2 show the sample distributions for the considered outcome measures.

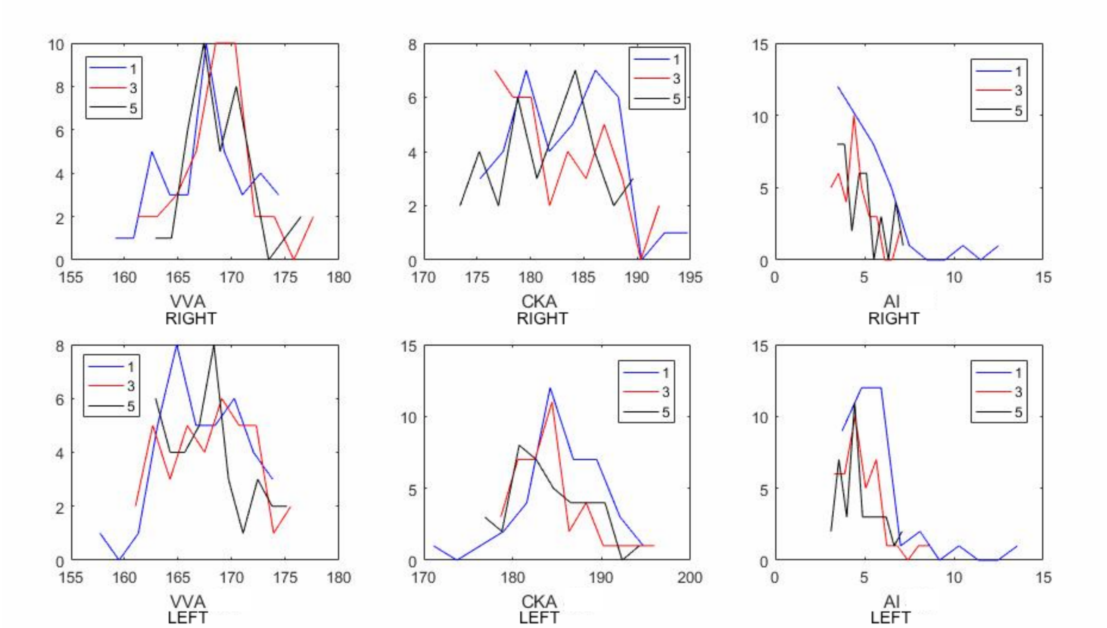
Figure 1- sample distribution for CCA, LPA, TTA, and FBI, at Stage 1, 3, and 5.



x-axis=number of subjects; CCA/LPA/TTA y-axis=degrees, FBI y-axis=centimetres.

Blue line=stage 1, red line=stage 3, black line=stage 5.

Figure 2- sample distribution for right/left VVA, CKA, and AI, at Stage 1, 3, and 5.



x-axis=number of subjects; VVA/CKA y-axis=degrees, AI y-axis=absolute value.

Blue line=stage 1, red line=stage 3, black line=stage 5.

The following Table 1 shows the p-values, by considering the longitudinal study; By considering the data distribution, I applied the paired Wilcoxon signed rank test, with the Bonferroni's correction (for three degrees of freedom). The following data show the impact of the prevention protocol on the participants' posture. The p-values demonstrate some significant difference (at $p<0.05$) between the three stages of the study.

Table 1- emerging results from the postural assessment through the photogrammetric software.

Posture	Range Stage 1	P-value St.1-3	Range Stage 3	p-value St.3-5	Range Stage 5	p-value St.1-5
CCA	27.2°-54.7°	(-) 0.0007**	26.9°-53.4°	0.0003**	29.9°-53.9°	2.5335
LPA	11.3°-59.4°	0.0039**	5.4°-36-6°	1.2200	4.6°-40.2°	0.0051**
Right VVA	158.3°-175.2°	0.1585	160.3°-178.5°	2.2959	162.1°-176.5°	0.1141
Left VVA	156.8°-174.7°	0.7376	160.2°-176.5°	1.2252	162.2°-175.8°	1.5557
TTA	93.5°-105.3°	0.7143	91.1°-108.4°	0.01122	89.7°-103.9°	0.0004**
Right CKA	174.2°-195.8°	0.4848	175.8°-192.9°	2.3821	172.5°-190.5°	0.5235
Left CKA	169.8°-196.0°	0.0463*	177.7°-196.9°	1.2376	175.9°-195.2°	0.0532
Right AI	3.0-13.0^	0.0307*	2.89-7.16^	0.5252	3.27-7.36^	0.3223
Left AI	3.17-14.10^	0.1208	2.95-8.92^	1.7002	2.97-7.32^	0.0671
FBI	0.0-28.3 cm	0.0021	0.0-16.9 cm	(-) 0.0001**	0.0-26.8 cm	0.6172

*Significant outcome at $0.05<p<0.01$; **extremely significant outcome at $p<0.01$; (-) negative difference; ^absolute values.

The following Table 2 describes the posture of the participants during this longitudinal study.

Table 2- qualitative analysis of the postural changing in the sample.

Posture	Stage 1	Stage 3	Stage 5
CCA	89.47% forward head	97.37% forward head	86.84% forward head
LPA	78.95% stiff hamstrings	52.63% stiff hamstrings	42.11% stiff hamstrings
Right VVA	94.74% valgus	94.74% valgus	94.74% valgus
Left VVA	97.37% valgus	94.74% valgus	94.74% valgus
TTA	100% stiff	100% stiff	97.37% stiff
Right CKA	39.47% curved	34.21% curved	21.05% curved
Left CKA	60.53% curved	42.11% curved	34.21% curved
Right AI	28.95% flat foot	13.16% flat foot	21.05% flat foot
Left AI	42.11% flat foot	16.32% flat foot	26.32% flat foot
FBI	89.47% stiff hamstrings	97.37% stiff hamstrings	81.58% stiff hamstrings

Values expressed in percentages (of participants).

In the following paragraphs I am going to show the results of the entire sample; then gender, age, and speed of growth stratifications are provided.

The following Tables 3 and 4 provide the p-values of the longitudinal analysis (Wilcoxon sign rank test), separating female and male participants. Through this analysis, I am able to identify the distribution of the changes.

Table 3 – emerging results from the postural assessment of the female population (n=13).

Posture	P-value St.1-3	p-value St.3-5	p-value St.1-5
CCA	(-) 0.0002**	0.0081**	0.2439
LPA	0.5417	0.9697	0.6848
Right VVA	0.5417	0.1475	0.0681
Left VVA	0.3054	0.2163	0.3757
TTA	0.2166	0.2734	0.0002**
Right CKA	0.4973	0.7869	0.6221
Left CKA	0.4548	0.3757	0.9460
Right AI	0.0005**	0.1465	0.0046**
Left AI	0.0134*	0.3757	0.0171*
FBI	0.1602	0.1475	0.9658

*Significant outcome 0.05<p<0.01; **extremely significant outcome at p<0.01. (-) negative difference.

Table 4 – emerging results from the postural assessment of the male population (n=25).

Posture	P-value St.1-3	p-value St.3-5	p-value St.1-5
CCA	(-) 0.342*	0.0038**	0.4223
LPA	0.0002**	0.3123	0.0007**
Right VVA	0.0802	0.5782	0.2522
Left VVA	0.6150	0. 7712	0.7915
TTA	0.4733	0.0851	0.0136*
Right CKA	0.1336	0.7519	0.1073
Left CKA	0.0008**	0.0255*	0.0013**
Right AI	0.3254	0.4481	0.9158
Left AI	0.5077	0.8949	0.3902
FBI	0.0017**	(-) <0.0001	0.0650

*Significant outcome 0.05<p<0.01; **extremely significant outcome at p<0.01. (-) negative difference.

The cross-sectional analysis, which compares males and females, is not provided, because it doesn't fit with the purpose of this study. I just provide this gender stratification to deeply describe the postural evolution in the sample.

After the previous gender stratification, I suggest another stratification.

To exclude the influence of the height growth on the postural improvements, I also provide a stratification of the sample considering the speed of growth. The following Table 6 shows the postural attitude of the children grown more than 9 cm (9cm=median of growth) in one year, compared to the others. I just provide data about the last period of study (between Stage 3 and Stage 5). Also in this part of the analysis, a comparison between populations has not been provided because of the descriptive purpose of this assessment.

Table 5 – emerging data about the population considering the speed of growth.

Posture	Rapid growth (>9cm in 1 year)	Normal growth (<9cm in 1 year)
CCA	0.0250*	0.0014**
LPA	0.9399	0.7012
Right VVA	0.4263	0.2290
Left VVA	-0.0739*	0. 9729
TTA	0.1928	0.1470
Right CKA	0.4332	0.2722
Left CKA	0.4332	0.1907
Right AI	-0.0833*	0.8117
Left AI	0.5619	0.8949
FBI	-0.0574 *	-0.0002**

*Significant outcome 0.05<p<0.01; **extremely significant outcome at p<0.01. (-) negative difference.

Finally I propose a comparison between the older and the younger participants is here provided. Table 7 shows the cross-sectional study (unpaired Mann & Withney test, for non-parametric data) of the children born in 2007 and 2008 (younger), and the children born in 2004, 2005 and 2006 (older).

Table 6 – Cross-sectional study after age stratification (younger and older).

Posture	p-value Stage 1	p-value Stage 3	p-value Stage 5
CCA	0.5859	0.1733	0.0873
LPA	0.6607	0.7392	0.1932
Right VVA	0.6828	0.2145	0.0241* (o)
Left VVA	0.6828	0. 1639	0.0242* (o)
TTA	0.3719	0.8917	0.5550
Right CKA	0.5859	0.5551	0.2091
Left CKA	0.8559	0.4137	0.7278
Right AI	0.0874	0.8205	0.3884
Left AI	0.019* (y)	0.9879	0.7853
FBI	0.0609	0.0048** (y)	0.5524

*Significant outcome 0.05<p<0.01; **extremely significant outcome at p<0.01. (-) negative difference.

Taking into account the previous data, I have provided an assessment of the complete sample, followed by a more specific evaluation, which considers some peculiarities of the subjects.

DISCUSSION

The aim of this study was trying to intervene in children's posture by proposing a prevention protocol during the basketball training. By teaching specific abilities, strengthening and stretching different muscles, I would improve the children's posture and way to move. I focused on exercises, which could help to reach a balanced body (in terms of muscles length and strength), extremely necessary to prevent LBP and other muscle-skeletal injuries. The statistical analysis, described in Table 1, shows some significant modification between the beginning and the end of this study (Stage 1 – Stage 5) of LPA (p-value=0.0051), left CKA (p-value=0.0532), and TTA (p-value<0.0004).

The LPA improves during the two years of intervention; in fact, the 78.95% of children with stiff hamstrings –opened LPA– becomes 52.63% at Stage 3 and 42.11% at Stage 5. The global and selective stretching seems to impact on the elasticity of the hamstrings. According to Belanguè and colleagues, closing the LPA could reduce one of the risk factors for the LBP.

Both the statistical (Table 1) and the qualitative analysis (Table 2) suggest that there are no changes on the varus/valgum knee attitude. This outcome can't be considered as positive, also because the VVA doesn't improve by the time.

Totally, the 94.74% of the participants has both valgus knees. The dynamic movements, the strengthening of gluteus and quadriceps, the stretching have not been sufficient to bring a modification on the attitude of the knees. This outcome is worrying because of the many injuries linked to the valgus attitude of the knees, like for example the Anterior Cruciate Ligament injury (Hewett, 2010)[26] or osteoarthritis (Lerner, 2015)[27]. According to Olsen (2005)[28], the sport practice can increase the risk of knee injuries, because of the mechanical stress that the joints are suffering. The protocol I proposed had been a reduced impact on this problem. More efforts and exercises should be included to have a satisfying result on the knees orientation. I also suppose that early cognitive training could teach the children how to move their lower limbs, consequently influencing these outcomes. The self-consciousness about the position of the knee in the space, could be a useful support, in order to teach the knee a different attitude.

Still considering the knees, the left CKA improves during the study and the percentage of children with a curved left knee reduces from 60.53% to 34.21% (Stage 3 = 42.22%). The qualitative analysis (Table 2) demonstrates that the percentage reduces also for the right knee (39.47% Stage 1; 34.21% Stage 3; 21.05% Stage 5). Even if the quantitative data don't support these changes, I can affirm that the proposed protocol had been a starting point, in order to reduce some curved knee in the participants.

The statistical analysis (Table 1) shows that the TTA modifies with an extremely significant p-value (0.0004). Considering the cut-off value, I know that a TTA>90° means stiff hamstrings. Even if the p-value suggests a large improvement in this joint, in Stage 1 and Stage 3 the joint range of the ankle is almost never lower than 90° (Stage 1= 93.5°-105.3°; Stage 3= 91.1°-108.4°; Stage 5= 89.7°-103.9°). A consistent improvement has taken place, but it is not enough to bring the participants below the cut-off; in fact, the percentage of children with an opened TTA (stiff hamstrings) changes just from 100% to 97.37%. I can affirm that the hamstrings stiffness changings are especially due to the large LPA improvements than the reduced TTA modifications. This means that the prevention protocol should be implemented, in order to improve the elasticity of the complete lower limb.

The statistical analysis demonstrates no significant changes for both AIs. Nevertheless, it is interesting that the percentage of children with flat foot has been reduced for both feet. In particular the percentage changes from 28.95% to 21.05% for the right foot, and from 42.11% to 26.32% for the left foot (Table 2).

The CCA and the FBI don't have a statistical improvement between Stage 1 and Stage 5 (Table 1), but they show significant p-values during the intermediate stages of the study (CCA p-value=0.0003; FBI p-value=0.0001).

The CCA gets worse in the first part of the study with a negative p-value of 0.0007, but improves between Stage 3 and 5 with a positive p-value of 0.0003 (Table 1). The starting worsening is not clear, but it is possibly due to the beginning difficulties of the children in practising the exercises. In fact, the incorrect position of the head during the exercises was one of the most important compensation during the first part of the study. By practising the exercises, the children have been able to improve this aspect. In fact, the percentage of children with a forward head position decreases from 89.47% at Stage 1 to 86.84% at Stage 5 (Table 2).

For the FBI the pathway has been the same, with a p-value of 0.0021 between Stage 1 and 3. I can justify this outcome, because, at the beginning, the children concentrated a lot on the FBI because they would improve their "personal record", by decreasing their own hand-floor distance. In the second part of the study, their attention on this aspect decreased (negative p-value of 0.0001). However, the percentages of children with a wide FBI decrease from 28.95% at Stage 1 to 21.05% at Stage 5.

Considering the qualitative analysis (Table 2), I can definitely affirm that the participants improve their postural attitude for the entire considered items. The two-years-long assessment demonstrates changes in the sample. Between Stage 1 and Stage 5, the percentage of participants with the forward head attitude reduces from 89.47% to 86.84%. The stiffness of the hamstrings reduces: from 78.95% to 42.11% of the sample considering the LPA; from 100% to 97.37% considering the TTA; from 89.47% to 81.58% considering the FBI. The right knee always remains valgus for the entire duration of the study in 94.74% of the participants. For the left knee instead, the percentage decreases from 97.37% to 94.74%. The curved knee affects from 39.47% to 21.95% of the participants in the right limb, and from 60.53% to 34.21% in the left knee. The AI, -representing the flat feet posture- reduces from 28.95% to 21.05% in the right foot, and from 60.53% to 34.21% in the left foot.

This postural attitude improvement is an important goal for a longitudinal prevention program. However, the lack of a control group remains a consistent issue in order to define the real validity of this protocol. Taking into account references of Belagué et al.[9] and Skoffer et al.[11], the basketball practice is considered a risky factor for several injuries. This activity has also an impact on the postural attitude of the athletes. For these reasons I could assume, that proposing the prevention exercises could lead to a postural benefit indeed. In a high specific sport practice, the proposal of global and active stretching, of stability and balance exercises could just enrich the activity itself.

The sample had been stratified by separately considering female and male participants. The female sample (Table 3) consists of 13 girls, of a mean-age of 12.08 years (SD=1.60). Between Stage 1 and Stage 3 they demonstrate a statistically significant negative change in CCA (negative p-value=0.0002), probably due to the beginning head compensation during the exercises. Between these stages, the females also demonstrate an improvement in both AI values (right p-value=0.0005, left p-value=0.0134). Between Stage 3 and Stage 5 they show a statistically significant improvement in CCA (p-value=0.0081), which brings the CCA to the beginning values. Between Stage 1 and Stage 5 they demonstrate a statistical significant improvement in TTA (p-value=0.0002), and both AI (right p-value=0.0046, left p-value=0.0171). Taking into consideration these data, during two years of activity, the postural attitude of the female participants have especially changed in the lowest part of the lower limb, in particular on ankle and foot. The male sample (Table 4) consists of 25 boys, of a mean-age of 11.48 years (SD=1.45). Considering the CCA, the males behave like the females: they show a statistically significant negative changing between Stage 1 and Stage 3 (p-value=0.342), but a positive improvement between Stage 3 and Stage 5 (p-value=0.0038), which brings the CCA to the beginning values. The male sample demonstrates a TTA improvement between Stage 1 and Stage 5 (p-value=0.0136). Between Stage 1 and Stage 3 they also demonstrate a statistically significant improvement of LPA (p-value=0.0002), which remains for the entire two-year period (Stage 1 – Stage 5 p-value=0.0007). The left CKA gradually improves with the following p-values: 0.0008 (Stage 1 - Stage 3), 0.0255 (Stage 3 – Stage 5), and 0.0013 (Stage 1 – Stage 5). At the beginning of the study the FBI improves (p-value=0.0017), but this outcome doesn't maintain because of the worsening between Stage 3 and Stage 5 (negative p-value=0.0001).

From the previous data, I can assume that the male sample especially improves in the hamstrings elasticity both in lumbar-pelvic and tibial-tarsal region. In order to verify the gender differences of the postural attitude, this analysis is necessary; nevertheless, a cross-sectional study is not provided, because my aim is to describe the peculiarities of the subgroups and not to strictly compare them.

In this study, I consider the speed of growth as possible influence factor (Table 5), which could have an impact on the postural development of the participants. Considering the last part of the study, I provide the p-values about the postural attitude of the stratified sample. The entire sample (rapidly and normally growth participants) shows a significant improvement in CCA and a negative change in FBI. There are no differences between the two groups. From these outcomes I can affirm that the growth rapidity doesn't have an impact on the postural attitude of the participants. To verify the impact of a quick growth on the postural attitude, this analysis is necessary; nevertheless, a cross-sectional study a cross-sectional study is not provided, because my aim is to describe the peculiarities of the subgroups and not to strictly compare them.

The last stratification, that I propose, divides older and younger participants. I provide a cross-sectional study of these samples to assess the postural development during different evolutional phases (Table 6). The two groups compare for several items. However, at Stage 1 they differ in the left AI (p-value=0.019), and at Stage 3 they differ in the FBI (p-value=0.0048). The data demonstrate that the younger participants are closer to the physiological cut-off for both the items. At Stage 5, the older participants demonstrate a smaller incidence of VVA for both the knees (right p-value=0.0241; left p-value=0.0242). This comparison highlights that there are no large differences in the postural development of younger and older participants. Anyway, the symmetric improvement of the older sample in the valgus knee, suggests that in this sample the correct postural knee adaptation is reached closer to the 14 years of age. This outcome could have interesting implications on the choice of the exercises to propose in a prevention program.

CONCLUSION

The main aim of this study was to verify the impact of a prevention protocol on a basketball players' sample, in order to prevent LBP and other muscle-skeletal disorders. The sample has practised the proposed exercises once a week, for two basketball seasons. In this period no participants suffered from LBP or other muscle-skeletal pain.

Even if the quantitative analysis demonstrates small changes, the qualitative assessment highlights several differences about the postural attitude of the entire sample. Moreover, these changes could be useful to increase the motor abilities and to improve the basketball performances of the participants.

In order to deepen the specific impact of this prevention program, in the future, I aim to introduce a control group. In the meantime, I can affirm that the introduction of such a protocol of stability, stretching, balance exercises could help sporty children to reduce the risk factors for muscle-skeletal injuries indeed.

BIBLIOGRAPHY

[1] Newell, K. M., Van Emmerik, R. E. A., & McDonald, P. V. (1989). Biomechanical constraints and action theory. *Human Movement Science*, *8*, 403-409.

[2] Watson, K. D., Papageorgiou, A. C., Jones, G. T., Taylor, S., Symmons, D. P., Silman, A. J., & Macfarlane, G. J. (2002). Low back pain in schoolchildren: occurrence and characteristics. *Pain*, *97*(1-2), 87-92.

[3] Calvo-Muñoz, I., Gómez-Conesa, A., & Sánchez-Meca, J. (2013). Prevalence of low back pain in children and adolescents: a meta-analysis. *BMC pediatrics*, *13*(1), 14.

[4] Hill, J. C., Whitehurst, D. G., Lewis, M., Bryan, S., Dunn, K. M., Foster, N. E., ... & Sowden, G. (2011). Comparison of stratified primary care management for low back pain with current best practice (STarT Back): a randomised controlled trial. *The Lancet*, *378*(9802), 1560-1571.

[5] Burton, A. K., Balagué, F., Cardon, G., Eriksen, H. R., Henrotin, Y., Lahad, A., ... & Van Der Beek, A. J. (2006). Chapter 2 European guidelines for prevention in low back pain. *European Spine Journal*, *15*, s136-s168.

[6] Hands, B.P., Parker, H., & Larkin, D. (2002). What do we really know about the constraints and enablers of physical activity levels in young children?.

[7] Wall, A. T. (2004). The developmental skill-learning gap hypothesis: Implications for children with movement difficulties. *Adapted physical activity quarterly*, *21*(3), 197-218.

[8] Cairney, J. (Ed.). (2015). *Developmental coordination disorder and its consequences*. University of Toronto Press.

[9] Balagué, F., Troussier, B., & Salminen, J. J. (1999). Non-specific low back pain in children and adolescents: risk factors. *European spine journal*, *8*(6), 429-438.

[10] Taimela, S., Kujala, U. M., Salminen, J. J., & Viljanen, T. (1997). The prevalence of low back pain among children and adolescents: a nationwide, cohort-based questionnaire survey in Finland. *Spine*, *22*(10), 1132-1136.

[11] Skoffer, B., & Foldspang, A. (2008). Physical activity and low-back pain in schoolchildren. *European Spine Journal*, *17*(3), 373-379.

[12] Fett, D., Trompeter, K., & Platen, P. (2017). Back pain in elite sports: A cross-sectional study on 1114 athletes. *PloS one*, *12*(6), e0180130.

[13] Feldman, D. E., Shrier, I., Rossignol, M., & Abenhaim, L. (2001). Risk factors for the development of low back pain in adolescence. *American journal of epidemiology*, *154*(1), 30-36.

[14] Cardon, G., & Balagué, F. (2004). Low back pain prevention's effects in schoolchildren. What is the evidence?. *European spine journal*, *13*(8), 663-679.

[15] Budelmann, K., von Piekartz, H., & Hall, T. (2013). Is there a difference in head posture and cervical spine movement in children with and without pediatric headache?. *European journal of pediatrics*, *172*(10), 1349-1356.

[16] Gajdosik, R. L., Albert, C. R., & Mitman, J. J. (1994). Influence of hamstring length on the standing position and flexion range of motion of the pelvic angle, lumbar angle, and thoracic angle. *Journal of Orthopaedic & Sports Physical Therapy*, *20*(4), 213-219.

[17] Kapandji, A. I. (1970). The ankle. *The physiology of the joints*, *2*, 156-177.

[18] Nguyen, A. D., Boling, M. C., Slye, C. A., Hartley, E. M., & Parisi, G. L. (2013). Various methods for assessing static lower extremity alignment: implications for prospective risk-factor screenings. *Journal of athletic training*, *48*(2), 248-257.

[19] Loudon, J. K., Goist, H. L., & Loudon, K. L. (1998). Genu recurvatum syndrome. *Journal of Orthopaedic & Sports Physical Therapy*, *27*(5), 361-367.

[20] Cahuzac, J. P. H., Vardon, D., & Sales de Gauzy, J. (1995). Development of the clinical tibiofemoral angle in normal adolescents. A study of 427 normal subjects from 10 to 16 years of age. *The Journal of bone and joint surgery. British volume*, *77*(5), 729-732.

[21] Roth, S., Roth, A., Jotanovic, Z., & Madarevic, T. (2013). Navicular index for differentiation of flatfoot from normal foot. *International orthopaedics*, *37*(6), 1107-1112.

[22] Kuo, L., Chung, W., Bates, E., & Stephen, J. (1997). The hamstring index. *Journal of Pediatric Orthopaedics*, *17*(1), 78-88.

[23] Ferreira, E. A. G., Duarte, M., Maldonado, E. P., Burke, T. N., & Marques, A. P. (2010). Postural assessment software (PAS/SAPO): validation and reliabiliy. *Clinics*, *65*(7), 675-681.

[24] Braz, R. G., Goes, F. P. D. C., & Carvalho, G. A. (2017). Confiabilidade e validade de medidas angulares por meio do software para avaliação postural. *Fisioterapia em movimento*, *21*(3).

[25] Souza, J. A., Pasinato, F., Basso, D., Corrêa, E. C. R., & Silva, A. M. T. D. (2011). Biophotogrammetry: reliability of measurements obtained with a posture assessment software (SAPO). *Revista Brasileira de Cineantropometria & Desempenho Humano*, *13*(4), 299-305.

[26] Hewett, T. E., Ford, K. R., Hoogenboom, B. J., & Myer, G. D. (2010). Understanding and preventing acl injuries: current biomechanical and epidemiologic considerations-update 2010. *North American journal of sports physical therapy: NAJSPT*, *5*(4), 234.

[27] Lerner, Z. F., DeMers, M. S., Delp, S. L., & Browning, R. C. (2015). How tibiofemoral alignment and contact locations affect predictions of medial and lateral tibiofemoral contact forces. *Journal of biomechanics*, *48*(4), 644-650.

[28] Olsen, O. E., Myklebust, G., Engebretsen, L., Holme, I., & Bahr, R. (2005). Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. *Bmj*, *330*(7489), 449.

4. THE CORRELATION BETWEEN THE POSTURE AND THE BODY MASS INDEX: A QUALITATIVE ANALYSIS

By developing the previous study (Chapter 3), I have realized, that the posture is just on of the important aspects to consider, in order to educate, teach, or train children. This present part of the project is an intermediate step, which adds other different Newell's[1] individual constraints to the posture: height and weight. In the following chapter, I'm dealing with different variables, which can influence the motor development of the children; for their peculiarities, I analysed these variables through a descriptive qualitative analysis.

INTRODUCTION

In the last decades, the obesity is a common problem for children and adults population. The World Health Organization (WHO) considers the obesity an increasing problem, which affects all the age-bands[2]. Marques and colleagues (2013)[3] define obesity the most common illness, which brings many comorbidities, especially in the paediatric population. Hypertension and hyperlipidaemia are examples of obesity consequences. The Body Mass Index (BMI, 1972)[4] is worldwide used as an outcome measure to identify overweight and obesity. A superior BMI respects the 95th percentile, defines an obese child. For cultural and social aspects, each country adopts peculiar BMI tables, which consider age and sex[5].

In literature, there is evidence about the correlation between overweight and posture. Through the X-Ray absorptiometry, Taylor and colleagues (2006)[6] demonstrate that postural knees abnormalities are more common in obese children and adolescents. Souza and colleagues affirm that a higher obesity level corresponds to a higher valgus deformity. Moreover, the study of Gushue and colleagues (2005)[7] associate the non-physiologic valgus knee to obesity, ligaments laxity, and quadriceps deficit. Calvete (2004)[8] suggests that obesity causes a mechanic overcharge of the motor system and a postural misalignment. In fact, the frontal weight forwardly moves the centre of mass, by modifying the feet's function. For this reason, overweight and obesity can cause a pronate posture of the feet. The anterior location of the weight -caused by the obesity-also characterizes the back posture. Legaye and colleagues (1998)[9] demonstrate the importance of the pelvic anatomy on the sacral inclination and on the back lordosis. In their study, Smith and colleagues (2008)[10] affirm that the overweight influences the back hyperlordosis, which impacts on the stand-up posture of adolescents.

Because of the strict correlation between posture and biomechanics, all these overweight-related postural aspects have an impact on the motor development of children and adolescents. Knees, back and feet attitude influences the ability to freely move and to evolve the motor skills.

The present study takes into account a sample of young basketball players. The first purpose is to identify height-and-weight conditions of these sporty children, who are playing basketball three-times a week. In the actual context, these children are considered active and sporty because they're practising sport at a competitive level. I am investigating the real possibility of these children to play basketball in the correct way, without the risk of more compromising their posture. Moreover, through a qualitative analysis, I would point out the postural aspect of overweight and obese children, who are playing basketball. The final aim is to give some implications about the importance of the weight and the posture control, even for a sporty child. These implications could lead the educators, the teachers and the coaches to take into account the physical and postural attitude of the children, before proposing them some sport activity or gesture.

MATERIALS AND METHODS

The Ethics Committee of the University of Trieste approved this study. All the parents of the children read and signed the written informed consent.

The players were recruited in a basketball Club of Trieste (Pallacanestro Interclub Muggia). In this club, the young players practice 3 basketball trainings a week, and already play the games versus other Clubs. They play basketball at a competitive, intense level, since at least two years.

Participants

A total of 42 participants (28 boys and 14 girls) were recruited. The mean age was 11.88 years (SD = 1.07). The inclusion criteria were: being born between 2004 and 2008, playing basketball at a competitive level, participating to the three-times-for week-basketball training. During the last two sport seasons, all the children participated in the prevention program, proposed by physical therapists, and described in the Chapter 3.

Procedure

During the basketball training, in a private and calm place of the gym, at the same time I proposed the BMI evaluation, and the photogrammetric postural assessment through the validated digital system of postural analysis SAPO (Ferreira, 2018)[11]. The existing literature supports this kind of assessment, which demonstrates satisfying level of reliability[12 13]. For the BMI assessment, I used a weight scale and a meter; I referred to Italian tables to identify the BMI percentile, by Cacciari and colleagues[5].

I put markers an the following point: tragi, spinal process of C7, T3, T7, L1, L3, L5, anterior-superior iliac spines, posterior-superior iliac spines, femurs (greater trochanter), knees (articular line), patellae (medium point), legs (point a medial line), calcaneal tendon between malleolus, and malleoli. To mark the points I positioned styrofoam balls (15 cm circumference) using double-faced adhesive tape. The camera (Nikon Coolpix L100) were placed on tripods (height of 1.50) with an angle of 90 degrees (same distance). The camera was placed 2 meters from the subject. A plumb line marked with two styrofoam balls was used for vertical calibration. I took 8 pictures for each subject: anterior frontal standing, posterior frontal standing, left-side sagittal standing, right-side sagittal standing, right-side sagittal forward bending, posterior frontal view of the feet, left-side sagittal view of one foot, right-side sagittal view of the other foot. In all the assessing stages I took the same number of pictures. Then, I analyzed the pictures through the software SAPO v0.68 in the Physiotherapy University of Trieste, by focusing more on the attitude of knees and back – as suggested from the scientific literature.

After collecting and analyzing all the data, I focused our examination on the overweight and obese children, to describe deeply their posture.

Referring measurements

I refer to literature to verify the postural situation of the sample. The considered measures are the Cranio-Cervical Angle (CCA), the Lumbar-Pelvic Angle (LPA), the Tibio-Tarsic angle (TTA), the Curved Knee Angle (CKA), the Varum/Valgum knee Angle (VVA), the Arch Index (AI).

- The CCA is composed by the intersection between the horizontal line which passes through C7, and the intersection line which touches C7 and the tragus. 51.25° is the cut-off value to discriminate a physiological head position or a forward head (<51.25°)[14].
- The LPA is considered in forward bending. It is composed by the intersection between the line, which touches the anterior-superior iliac spine and the posterior-superior iliac spine, and the line which touches the great trochanter and the articular line of the knee. Whether the angle is < 12.6° the hamstrings are considered elastic. The angle included between 12.6° and 22.5° refers to a normal elasticity of the hamstrings. The angle > 22.5° defines stiff hamstrings. This is an important value to consider the incidence of LBP[15].
- The TTA is considered in forward bending. It is composed by the horizontal line, which touches the lateral malleolus, and the line which passes through the articular line of the knee and the lateral malleolus. The cut-off value is 90°[16].
- The CKA is the angle between the line, which touches the great trochanter, and the articular line of the knee, and the line which touches the articular line of the knee and the lateral malleolus[17]. The cut-off value is 185°[18].
- The VVA is composed by the intersection of the line, which passes through the anterior-superior iliac spine and the medium point of the patella, and the line which passes through the medium point of the patella and the lateral malleolus. The cut-off value to consider a valgus knee is 174.5°[19].
- The AI comes from the relation between the length and the height of the plantar arch. The AI>6.74 defines a flat foot[20].

Limitations

The small number of participants, the large age-band considered, not the possibility to afford a deep quantitative analysis are all limits of this study.

RESULTS

The sample consists of 28 boys and 14 girls who are playing basketball. In the following Table 1, all the outcomes are listed.

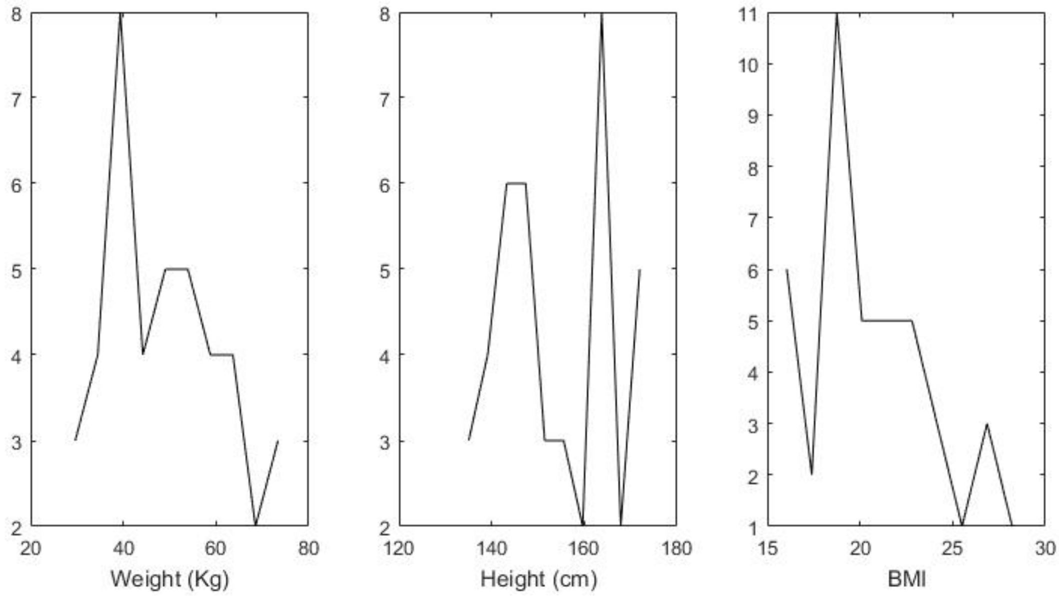
Table 1. Weight, height and BMI assessment of the sample.

	Male	Female	All
M-weight	47.33	53.38	49.58
SD-weight	12.63	12.14	12.65
M-height	1.52	1.56	1.54
SD-height	0.12	0.11	0.12
M-BMI	20.16	21.56	20.68
SD-BMI	3.18	3.35	3.26
M-age	11.64	12.21	11.88
SD-age	1.45	1.63	1.51
n	28	14	42

M=mean; SD=standard deviation; n=number of participants. Weight expressed in kilograms; height expressed in metres. BMI is an absolute value.

The BMI derives from a calculation between height and weight, considering the age-band and the gender. After considering all these aspects, the BMI permits to identify the physical development percentile of growth[4]. The following Figure 1 shows the distribution of this sample, by taking into account weight, height and BMI.

Figure 1 – Weight, height and BMI distribution of the sample.



x-axis=number of subjects.

The following qualitative analysis of the sample gives more information about these aspects.

34 children on 42 have a normal weight. The 16.67% of the sample (7 children on 42) is overweight or obese (OW). In particular, 4 (3 males, 1 female) children are overweight and 3 (1 male, 2 females) children are obese. Table 2 summarises the characteristics of these participants.

Table 2. Qualitative analytic description of OW.

Subjects	Age	BMI	Percentile	Outcome
M1	13	26.36	90-95	overweight
M2	13	28.88	97-99	obese
M3	10	22.91	90-95	overweight
M4	10	23.30	90-95	overweight
F1	14	24.88	85-90	overweight
F2	11	27.35	97-99	obese
F3	11	26.43	95-97	obese

M=male, F=female. BMI - absolute value, Percentile - ordinal value.

In the following paragraphs, I describe the analytic postural attitude of these subjects. The assessment has been compared to the referring measures, listed in the Materials and Methods.

The male subject number 1 (M1) is overweight. He has a CCA of 46.5°, which relates to a forward position of the head. The LPA of 9.0°, defines elastic hamstrings. The TTA of 97.6° defines the stiffness of the joint. The knees are both valgus (right 168.5°, left 167.7°), but the left knee is also curved (187.5°, right knee 182.7°). The feet are not flat (right AI=5.1, left AI=4.5).

The male subject number 2 (M2) is obese. He has a CCA of 31.3°, which relates to a forward position of the head. The LPA of 28.4°, confirms the stiffness of the hamstrings. The TTA of 98.3° defines the stiffness of the joint. The knees are both valgus (right 161.2°, left 163.7°), and curved (right 186.5°, left 187.2°). The feet are flat (right AI=7.7, left AI=7.4).

The male subject number 3 (M3) is overweight. He has a CCA of 38.4°, which relates to a forward position of the head. The LPA of 20.9°, defines a normal elasticity of the hamstrings. The TTA of 93.1° defines the stiffness of the joint. The knees are both valgus (right 168.2°, left 168.6°), but not curved (right 172.6°, left 181.3°). The feet are not flat (right AI=4.0, left AI=4.2).

The male subject number 4 (M4) is overweight. He has a CCA of 42.5°, which relates to a forward position of the head. The LPA of 18.7°, defines a normal elasticity of the hamstrings. The TTA of 94.4° defines the stiffness of the joint. The knees are both valgus (right 165.2°, left 162.4°), but not curved (right 184.4°, left 182.6°). The feet are not flat (right AI=4.0, left AI=3.6).

The female subject number 1 (F1) is overweight. She has a CCA of 37.8°, which relates to a forward position of the head. The LPA of 4.6°, defines elastic hamstrings. The TTA of 102.3° defines the stiffness of the joint. The knees are both valgus (right 170.9°, left 168.3°), and curved (right 186.0°, left 186.2°). The feet are not flat (right AI=4.0, left AI=3.7).

The female subject number 2 (F2) is obese. She has a CCA of 34.2°, which relates to a forward position of the head. The LPA of 27.1°, defines the stiffness of the hamstrings. The TTA of 96.9° defines the stiffness of the joint. The knees are both valgus (right 164.7°, left 162.1°), but not curved (right 185.4°, left 184.5°). The feet are flat (right AI=6.9, left AI=6.7).

The female subject number 3 (F3) is obese. She has a CCA of 32.4°, which relates to a forward position of the head. The LPA of 15.4°, defines a normal elasticity of the hamstrings. The TTA of 98.7° defines the stiffness of the joint. The knees are both valgus (right 167.6°, left 162.9°), and curved (right 186.5°, left 187.2°). The feet are not flat (right AI=3.4, left AI=3.5).

The following Table 3 summarizes the postural attitude of this peculiar sample.

Table 3. OW alterations posture summary.

	n	CCA	LPA	TTA	Right VVA	Left VVA	Right CKA	Left CKA	Right AI	Left AI
Overweight male	3	100%	0%	100%	100%	100%	0%	33.33%	0%	0%
Obese male	1	100%	100%	100%	100%	100%	100%	100%	100%	100%
Overweight female	1	100%	0%	100%	100%	100%	100%	100%	0%	0%
Obese female	2	100%	50%	100%	100%	100%	50%	50%	50%	50%

Percentages of children who show postural alterations in the following item: CCA (Cranio-Cervical Angle), LPA (Lumbar-Pelvic Angle), TTA (Tibio-Tarsic Angle), VVA (Varum-Valgum Angle), CKA (Curved Knee Angle), AI (Arch Index).

The following Table 4 summarizes BMI and growth percentiles of the 35 normal-weight children of the sample (NW).

Table 4. NW BMI and percentiles ranking.

n	F	M	m-BMI	SD-BMI	Percentile	Outcome
9	3	6	22.52	1.20	75-85	normal-weight
10	4	6	19.93	1.16	50-75	normal-weight
10	3	7	18.52	1.14	25-50	normal-weight
5	0	5	16.72	1.14	10-25	normal-weight
1	1	0	15.38	-	5-10	normal-weight

n=number of subjects; M=male, F=female. m-BMI=mean-BMI; SD-BMI=standard deviation of BMI. Percentile - ordinal value.

The Table 5 summarizes the postural attitude of males and females participants of NW.

Table 5. NW alterations posture summary.

	n	CCA	LPA	TTA	Right VVA	Left VVA	Right CKA	Left CKA	Right AI	Left AI
Male	24	85.71%	46.43%	96.43%	89.29%	92.86%	21.43%	28.57%	10.71%	7.14%
Female	11	92.86%	42.86%	100%	92.86%	100%	42.86%	57.14%	7.14%	21.43%

Percentages of children who show postural alterations in the following item: CCA (Cranio-Cervical Angle), LPA (Lumbar-Pelvic Angle), TTA (Tibio-Tarsic Angle), VVA (Varum-Valgum Angle), CKA (Curved Knee Angle), AI (Arch Index).

Taking into account the NW children, the following data describes the most common postural attitude. The assessment has been compared to the referring measures, listed in the Materials and Methods. I am not going to describe one-by-one the members of the NW, because of the quantity, and because in this work I especially analytic focus on OW. The following data describe the postural attitude of males and females of the NW

All the previous data are necessary to assess and determine the posture of the sample, considering to reference measures. These cut-off values permit to understand whether the postural items are literally considered physiological or not. I have provided the gender stratification to deeply describe the children attitude. Nevertheless, the comparison between OW and NW don't consider gender differences, because in this age-band the cut-off values are the same for males and females.

To compare OW and NW I provide both quantitative and qualitative analysis.

The following Table 6 shows the p-values emerging from the quantitative comparison between OW and NW (Mann-Whitney test, for non parametric data). The limited number of the sample suggests providing a qualitative analysis too. In fact, the following Table 7 shows the qualitative comparison of OW and NW.

Table 6. Quantitative comparison between OW and NW.

Item	P-value
CCA	0.01*
LPA	0.13
TTA	0.70
Right VVA	0.36
Left VVA	0.06
Right CKA	0.95
Left CKA	0.75
Right AI	0.81
Left AI	0.68

CCA (Cranio-Cervical Angle), LPA (Lumbar-Pelvic Angle), TTA (Tibio-Tarsic Angle), VVA (Varum-Valgum Angle), CKA (Curved Knee Angle), AI (Arch Index), *significant difference at p<0.05.

Table 7. Qualitative comparison between OW and NW.

	n	CCA	LPA	TTA	Right VVA	Left VVA	Right CKA	Left CKA	Right AI	Left AI
Group 1	7	100%	28.57%	100%	100%	100%	42.86%	42.86%	14.29%	28.57%
Group 2	35	85.71%	48.57%	97.14%	88.57%	94.12%	25.71%	37.14%	8.57%	8.57%

Group 1=overweight and obese children. Group 2=normal-weight children. Percentages of children who show postural alterations in the following item: CCA (Cranio-Cervical Angle), LPA (Lumbar-Pelvic Angle), TTA (Tibio-Tarsic Angle), VVA (Varum-Valgum Angle), CKA (Curved Knee Angle), AI (Arch Index).

DISCUSSION

Obesity and overweight are risky factors for cardio-vascular, physical and metabolic diseases, but in the young population they also influence the psychosocial development (Cairney, 2015)[21]. They can affect both inactive and sporty children, or adolescents. In the present study I have considered young basketball players with different heights and weights. I have investigated about their BMI -consequently about their growth percentile-, and about their postural attitude. I would verify whether obese and overweight children who practice basketball exist, in my sample. To highlight possible postural differences, I have compared them to the normal-weight peers. I am interested in considering the real possibility of these children to play basketball without risking muscle-skeletal or postural problems.

The outcomes demonstrate that in a sample of 42 sporty children, the 16.67% rank in the overweight or obese growth percentile (Tables 1 and 2). This

percentage is worrying, because I am considering active children, who are playing basketball since at least two years, at a competitive level.
The OW consists of 3 obese (1 male and 2 females) and 4 overweight subjects (3 males and 1 females). In the early qualitative analysis (Table 3) I have found out, that there are a few differences in the postural attitude between obese and overweight subjects. The reduced number of participants imposes not to consider the gender differences; in this case, implications about gender-relation would not be consistent. 2 obese children (on the total of 3) demonstrate non-physiological values of LPA, both CKAs and both AIs.
All the obese children have non-physiological values of CCA, TTA, and both VVAs.
All the overweight children have non-physiological value of CCA, TTA, and both VVAs. The overweight have physiological values of LPA and both AIs. 3 children (on 4) have physiological values of the right CKA, and 2 children of the left CKA. These results are coherent with the references of Gushue[7], Calvete[8], and Legaye[9], who support the impact of the weight on some postural attitude.
The 35 children, who have a normal-weight, compose the NW (Table 4). The larger quantity of participants allows us making some implications about the gender postural differences (Table 5). The normal-weight females demonstrate more non-physiological postural values than the males. In fact, the percentage of males with non-physiological values is only higher for the LPA and the left AI items. It is interesting to highlight that the high number of females with postural alterations could be linked to their higher mean-BMI (females=21.56; males=20.16). Moreover, the high percentage of non-physiological items of female subgroup could be linked to gender anthropometric and anatomical measures (Hewett, 2005)[22]. According to the references of Beynnon (2011)[23] and Uhorchak (2003)[24] the percentage of female with valgus and curved knees is higher than the male one. This outcome could have a consequence also on the ankle attitude (Neumann, 2007)[25]; in this way the 100% of open TTA cold be explained.

Anyway, the main aim of this study is to compare the OW and NW. Because of the limited number of OW subjects, I don't differentiate males and females, in this analysis. The statistical quantitative analysis through the Mann-Whitney test shows a unique significant difference between OW and NW (Table

6); this outcome is probably due to the little size of the OW. The CCA is closer to physiological values in the NW. The higher mean-value of the obese and overweight children is coherent with Smith and colleagues' research[26]. In fact the authors affirm that the overweight influences the back hyperlordosis. Furthermore, Murphy and colleagues[27] (2004) highlight the correlation of back and neck posture. I can deduce that the overweight impacts on the back posture, which consequently influences the neck attitude –with a significant p-value (0.11). Anyway, the qualitative analysis (Table7) provides more data about the difference between the two groups. The 100% of the OW shows a forward head attitude. Smith and Murphy's[24 25] references could explain this outcome. However, the 85.71% of NW children shows a forward head attitude too. Anyway, the impact of the weight on the back could have a positive influence on the measure of the lumbar-pelvic angle of these children. In fact, for the LPA, the NW has more non-physiological values than the OW (OW 28.57%; NW 48.57%). The 100% of the OW shows valgus knees and stiff ankles. According to Neumann[23], these outcomes surely impact on the curved attitude of the knees (right 42.86%; left 42.86%) and on the flat feet posture (right 14.29%; left 28.57%). These percentages are quite smaller in NW (right VVA=88.57%, left VVA=94.12%; TTA=97.14). Furthermore the NW especially differs in the curved knees and in the flat feet for lower values. In conclusion, the qualitative analysis confirms a common postural attitude of OW, which shows a high percentage of several postural alterations – even without a statistical significance, due to the size of the OW. Anyway, also the percentage of normal-weight children with several postural alterations is consistent.

This work aims to verify the differences between these two groups.

In order to prevent injuries, and to improve the motor performances of these young athletes, the excessive weight is another negative factor, which could affect the posture too.

In this study I would reflect on the implications of overweight that these outcomes could have. The sport practice is a necessary and useful way to develop fitness, motor, social and emotional competences. Children and pre-adolescents must attend the gym or practice a sport, in order to increase their motor ability, to prevent physical and psychological diseases. Anyway, a deeper assessment of the sport to practice is necessary. For instance, basketball, volleyball and soccer furnish several joints stress, which could cause damages or worsen existing problems. In particular, basketball provides a well-known valgus stress of the knees. This aspect should be considered before starting this kind of practice, especially if the children demonstrate some physical problems, like the overweight and the obese children could. I am not supporting some activity at the expense of others. By the way, I suggest to take into account the own postural attitude, respect to the movement and the gesture the sport practice requires. This is not a duty of the children: the parents and the coaches should consider these aspects instead of them. They don't have to deny some particular activity; on the contrary they could propose an integrative corrective activity, to improve the postural attitude of the child.

The children of this sample made part of a Low Back Pain prevention program, which had improved their posture, but the results demonstrate that this was not enough (Chapter 3). In case of overweight and obese children, managing the nutrition is also necessary –this aspect is not considered in this paper-. By proposing the correct sport activity, parents and coaches should monitor the development of the body and the posture. In the modern sport, the coaches of the young players claim not to have enough time to develop all the required physical skills. For every sportsman or woman, developing a correct posture is a fundamental necessary competence to move in the correct way. If the coach can't afford this duty, especially for overweight and obese children, an integrative motor program should be included.

Finally, even if these children are playing basketball three times a week, the social context continuously offers them sedentary maintained postures, technological devices use, and static games at the expense of a correct postural and motor development. Moreover, in Italy the school activity at the gym just consists of two hours practice for week. The inclusion of a complete postural and motor specific program is necessary for all the children (underweight, normal-weight, overweight and obese). The specific sport trainings could not include all the postural requirements that the children have to adjust. These young players need something more than the fitness training, for the strength, the resistance and the cardio-respiratory outcomes. I suggest providing stretching, alignment, and balance exercises; I propose to work with eyes-closed, with a large self-attention on the own body. I would still highlight the importance of the team sport activity for obese and overweight children. This kind of proposal helps these specific children to face the fatigue with their peers. The isolation related to the weight problems reduces during this activity, which involve the obese children and improve their psychophysical conditions. The team sports are a protective factor respect the social involvement of these children[19].

CONCLUSION

The emerged outcomes and the consequent suggestions are all fundamental for children, who are practicing sport. The same implication widely involves the children who don't practice motor activities. In the childhood and in the adolescence, the physical activity is necessary to develop all the above-cited abilities and competences. The inactivity can have physical, social and postural consequences. Providing a non-competitive, flexible and enjoying activity could help the children to prevent several disease, and in particular several postural alterations. This implication is extended to all the children and young adolescents, even not considering their BMI. Taking into account their sedentary lifestyle during the time-school, and the consistent use of technological devices in the afternoon and in the evening, some postural-tips should also be given.

Increasing the consciousness of coaches, trainers and educators about these problems, could bring some changes about their way to teach and educate the motor abilities. Taking into account the importance to intervene on the motor memory and on the sensorimotor competencies could help the children to escape from negative constraints, like –in this case- the overweight.

BIBLIOGRAPHY

[1] Newell, K. M., Van Emmerik, R. E. A., & McDonald, P. V. (1989). Biomechanical constraints and action theory. *Human Movement Science*, *8*, 403-409.

[2] James, W. P. T. (2009). WHO recognition of the global obesity epidemic. *International journal of obesity*, *32*(S7), S120.

[3] Marques, T., Moniz, M., Cabral, M., Nizarali, Z., Coelho, R., Monteiro, A. C., ... & Carreiro, H. (2013). Obesidade infantil: caraterização de uma população com seguimento hospitalar. *Acta Pediátrica Portuguesa*, *44*, 295-300.

[4] Keys, A., Fidanza, F., Karvonen, M. J., Kimura, N., & Taylor, H. L. (1972). Indices of relative weight and obesity. *Journal of chronic diseases*, *25*(6-7), 329-343.

[5] Cacciari, E., Milani, S., Balsamo, A., Spada, E., Bona, G., Cavallo, L., ... & Cicognani, A. (2006). Italian cross-sectional growth charts for height, weight and BMI (2 to 20 yr). *Journal of endocrinological investigation*, *29*(7), 581-593.

[6] Taylor, E. D., Theim, K. R., Mirch, M. C., Ghorbani, S., Tanofsky-Kraff, M., Adler-Wailes, D. C., ... & Yanovski, J. A. (2006). Orthopedic complications of overweight in children and adolescents. *Pediatrics*, *117*(6), 2167-2174.

[7] Gushue, D. L., Houck, J., & Lerner, A. L. (2005). Effects of childhood obesity on three-dimensional knee joint biomechanics during walking. *Journal of Pediatric Orthopaedics*, *25*(6), 763-768.

[8] Calvete, S. A. (2004). Relationships between postural alterations and sports injuries in obese children and adolescents. *Motriz*, *10*, 67-72.

[9] Legaye, J., Duval-Beaupere, G., Hecquet, J., & Marty, C. (1998). Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. *European Spine Journal*, *7*(2), 99-103.

[10] Smith, A., O'sullivan, P., & Straker, L. (2008). Classification of sagittal thoraco-lumbo-pelvic alignment of the adolescent spine in standing and its relationship to low back pain. *Spine*, *33*(19), 2101-2107.

[11] Ferreira, E. A. G., Duarte, M., Maldonado, E. P., Burke, T. N., & Marques, A. P. (2010). Postural assessment software (PAS/SAPO): validation and reliabiliy. *Clinics*, *65*(7), 675-681.

[12] Braz, R. G., Goes, F. P. D. C., & Carvalho, G. A. (2017). Confiabilidade e validade de medidas angulares por meio do software para avaliação postural. *Fisioterapia em movimento*, *21*(3).

[13] Souza, J. A., Pasinato, F., Basso, D., Corrêa, E. C. R., & Silva, A. M. T. D. (2011). Biophotogrammetry: reliability of measurements obtained with a posture assessment software (SAPO). *Revista Brasileira de Cineantropometria & Desempenho Humano*, *13*(4), 299-305.

[14] Budelmann, K., von Piekartz, H., & Hall, T. (2013). Is there a difference in head posture and cervical spine movement in children with and without pediatric headache?. *European journal of pediatrics*, *172*(10), 1349-1356.

[15] Gajdosik, R. L., Albert, C. R., & Mitman, J. J. (1994). Influence of hamstring length on the standing position and flexion range of motion of the pelvic angle, lumbar angle, and thoracic angle. *Journal of Orthopaedic & Sports Physical Therapy*, *20*(4), 213-219.

[16] Kapandji, A. I. (1970). The ankle. *The physiology of the joints*, *2*, 156-177.

[17] Nguyen, A. D., Boling, M. C., Slye, C. A., Hartley, E. M., & Parisi, G. L. (2013). Various methods for assessing static lower extremity alignment: implications for prospective risk-factor screenings. *Journal of athletic training*, *48*(2), 248-257.

[18] Loudon, J. K., Goist, H. L., & Loudon, K. L. (1998). Genu recurvatum syndrome. *Journal of Orthopaedic & Sports Physical Therapy*, *27*(5), 361-367.

[19] Cahuzac, J. P. H., Vardon, D., & Sales de Gauzy, J. (1995). Development of the clinical tibiofemoral angle in normal adolescents. A study of 427 normal subjects from 10 to 16 years of age. *The Journal of bone and joint surgery. British volume*, *77*(5), 729-732.

[20] Roth, S., Roth, A., Jotanovic, Z., & Madarevic, T. (2013). Navicular index for differentiation of flatfoot from normal foot. *International orthopaedics*, *37*(6), 1107-1112.

[21] Cairney, J. (Ed.). (2015). *Developmental coordination disorder and its consequences*. University of Toronto Press.

[22] Hewett, T. E., Ford, K. R., Hoogenboom, B. J., & Myer, G. D. (2010). Understanding and preventing acl injuries: current biomechanical and

epidemiologic considerations-update 2010. *North American journal of sports physical therapy: NAJSPT*, *5*(4), 234.

[23] Beynnon, B. D., Johnson, R. J., Naud, S., Fleming, B. C., Abate, J. A., Brattbakk, B., & Nichols, C. E. (2011). Accelerated versus nonaccelerated rehabilitation after anterior cruciate ligament reconstruction: a prospective, randomized, double-blind investigation evaluating knee joint laxity using roentgen stereophotogrammetric analysis. *The American journal of sports medicine*, *39*(12), 2536-2548.

[24] Uhorchak, J. M., Scoville, C. R., Williams, G. N., Arciero, R. A., Pierre, P. S., & Taylor, D. C. (2003). Risk factors associated with noncontact injury of the anterior cruciate ligament. *The American journal of sports medicine*, *31*(6), 831-842.

[25] Neumann, H. W., Lieske, S., & Schenk, K. (2007). Supramalleolar, subtractive valgus osteotomy of the tibia in the management of ankle joint degeneration with varus deformity. *Operative Orthopadie und Traumatologie*, *19*(5-6), 511-526.

[26] Smith, A. J., O'Sullivan, P. B., Beales, D. J., De Klerk, N., & Straker, L. M. (2011). Trajectories of childhood body mass index are associated with adolescent sagittal standing posture. *International Journal of Pediatric Obesity*, *6*(sup3), e97-106.

[27] Murphy, S., Buckle, P., & Stubbs, D. (2004). Classroom posture and self-reported back and neck pain in schoolchildren. *Applied ergonomics*, *35*(2), 113-120.

5. THE KINEMATIC ASSESSMENT OF THE VERTICAL JUMP: A DESCRIPTIVE ANALYSIS

By considering the previous individual constraints, I realized that assessing the quality of the movement is also necessary. A photogrammetric analysis of the posture (Chapter 3) is important, but it is not enough.
In order to understand eventual alterations of this particular sample, I provide a biomechanical analysis of a normally used motor gesture: the vertical jump. This part of the study tries to enrich the evidence about the kinematic assessment of the jump in this specific population of sporty children. I focus on this specific task, which the children use during the basketball practice.
Taking into account the vertical jump, as necessary task to develop other motor abilities, I consider it as task-constraints.

INTRODUCTION

The jump is a complex movement, which allows the body to move upward into the air. It is an important motor ability, developed and trained also during the sport practice. In particular, during the basketball practice, the jump is useful to move closer to the basket, but also to reach the ball, or to throw the ball stronger. The players experiment and improve their jump ability through the practice. Young children, who start playing basketball, immediately begin to test their ability to jump and hop. In literature, researchers use the vertical jump to assess the muscular activation, the biomechanics properties, and the neuro-muscular mechanisms involved in this gesture[1 2]. In particular, there is evidence about the temporal joints activation, the elevation, the trajectory, the joints range of motion, the symmetry and the reactive forces of the jump of young and adult sporty people. Anyway, not all these aspects are considered in the literature about children, neither about children who play basketball.
In the late '80s, Clark and Phillips (1989)[3] studied the developmental differences between the vertical and the long jump in children aged between 3 and 9 years. Comparing the outcomes to the adult population, they verified that just the 3-

years-old children jumped differently from the adults. The researchers focused on peak velocities and joint strategies, referring to a camera-filmed assessment.
More recently, on the contrary, Swartz and colleagues (2005)[4] have found out that the children utilize a different jump strategy respect to the adults. They affirm that children's knees have a bigger valgus angle than the adults' one, and hips and knees are more extended and stiff during the landing.
Furthermore, Schiltz and colleagues (2009)[5] give an example of the influence of the sport practice on the jump abilities, depending on the level and on the age of training.
Meylan and colleagues (2012)[6] examined the jump kinetics and kinematics in athletes from 9 to 16 years. Their aim was to verify the reliability of concentric and eccentric kinematic and kinetic, as indicators of jump and stretch-shortening cycle performance. The authors concentrated on the force analysis of muscular efficiency indeed.

The present study aims to assess the jump biomechanics of young basketball players, in terms of joints range of motion. In this project, the jump is considered like outcome measure to verify the children's ability to move.
In literature, researchers describe different possibilities to jump, i.e. the drop vertical jump, single leg hop[7], countermovement jump with or without the arm-swing. In this study, I will consider the vertical jump[8], without the arm-swing. For my purposes, I refer to McGinnis' work (1999)[9], which describes three phases: a preparatory (or down) phase, a propulsive (or up) phase, and a flight phase. Considering the jump as symmetric, right and left move in the same way. During the preparatory phase the ankles dorsi-flex, the knees and the hips flex, and the shoulders hyperextend. The body is lowered, the angles of the joints are closed, and the contraction of the hip, knee and ankle muscles is eccentric. During the propulsive phase the ankles planti-flex and the shoulders flex. On the contrary, respect to the down phase, the body is extended, the joint angles are open, and the contraction of the muscles is concentric. For the range of motion analysis, I refer to Bobbert's and colleagues[10 11 12 13] reports. The authors assess the degrees of movement of the joints during the countermovement jump in an adult sample; the literature doesn't provide these data about the children. After a

radiant-degrees conversion, in the following Table 1 I provide the data, that these authors found out.

Table 1. Bobbert's and colleague joints outcomes (adult sample).

	Down-Mean	Down-SD	Up-Mean	Up-SD	Flight-Mean	Flight-SD
Hip	8.21°	11.46°	72.19°	12.60°	124.90°	6.30°
Knee	97.40°	11.46°	75.05°	5.15°	177.61°	4.58°
Ankle	85.94°	5.73°	64.17°	13.17°	168.45°	5.16°

Down-mean= mean range of the Down phase; Down-SD= SD of the Down phase; Up-mean= mean range of motion of the Up phase; Up-SD= SD of the Up phase; Flight-mean= mean range of motion of the Flight phase; Flight-SD= SD of the Flight phase. ° Values expressed in degrees.

Referring to the previous range of motion, and to the previous joints activation strategy, I aim to examine how the basketball players jump between 8 and 12 years of age. The examination of the peculiar aspects of the kinematics of the children could give data about the ability of the child to move. These outcomes could be helpful to find the correct way to train the jump and to help the young players to improve their abilities.

MATERIALS AND METHODS

First, the Ethics Committee of the University of Trieste approved this project. Two basketball Clubs guaranteed their participation in the study. The parents and the children read and signed the informed consent, and the acceptance module to participate in the study.

After the written consent I immediately collected the anamnestic data.

The inclusion criteria for this study were: to be aged between 8 and 12 years old, and to practice basketball at least 3 times for week for at least 2 years.

Procedures

The assessments occurred in a calm and quiet place in the basketball gym, during the basketball training. According to the coaches, one player exited from the play to be assessed. The assessment was 10 minutes long. Through the digital technology Mtw Awinda Development kit-ii® I assessed the kinematics of the vertical jump. The previous literature supports the reliability of this assessment technology[14].

The examination of the jump required three trials. After each jump, there were pauses of 30”. The feet position to start the jump had been freely chosen by each child, and I registered it on the floor with a tape. I applied the sensors on the dominant leg in the following key-points: above to the iliac crest (lateral), 8 cm up to the knee articular line on the femur (lateral), 8 cm down to the knee articular line on the fibula on the foot (lateral), on the foot (dorsal), and on the belly button (frontal, as projection of the barycentre).

I gave the same instructions to all the participants for all the three trials, to eliminate procedures biases. I exactly asked to:

- jump as high as possible
- imagine to obstacle another player
- put the hands on the hip (to eliminate the bias of the upper limbs strength during the jump)
- land after the jump without moving, as long as possible
- follow the vocal commands.

I provide the assessment of one of the three jumps. I chose the jump, in which the barycentre sensor produced fewer after-landing-oscillations.

<u>*Software and accelerometers*</u>

Mtw Awinda Development kit-ii®[14] has been used for the assessment of the vertical jump. This is a wireless portable system of MicroElectroMechanical, which consists of accelerometers, magnetometers, gyroscopes, barometers and thermometers. The sensors are wearable and they perform a sampling frequency of 1000 Hz. To collect the data I used the MT Manager Software. This software permits to verify the real-time 3D orientation, and to assess the inertial and the magnetic forces of the sensors. During the detection of the movements, the software provide a graphic representation of the following orientation Eulers: Yaw (direction of the sensor, which rotates on the Z-axis [-180°, 180°]), Pitch (elevation and inclination of the sensor, which rotates on the Y-axis [-90°, 90°]), Roll (rotation of the sensor, which rotates on the X-axis after the second rotation [-180°, 180°]).

In this study, I consider the relative angles of the joints. No absolute values of the limbs position have been measured and used. For this, the emerging measures don't need a previous tarature, because I'm looking for realtive values.
By exporting the data in Matrix Laboratory®, I afforded the calculation to analyse the data.

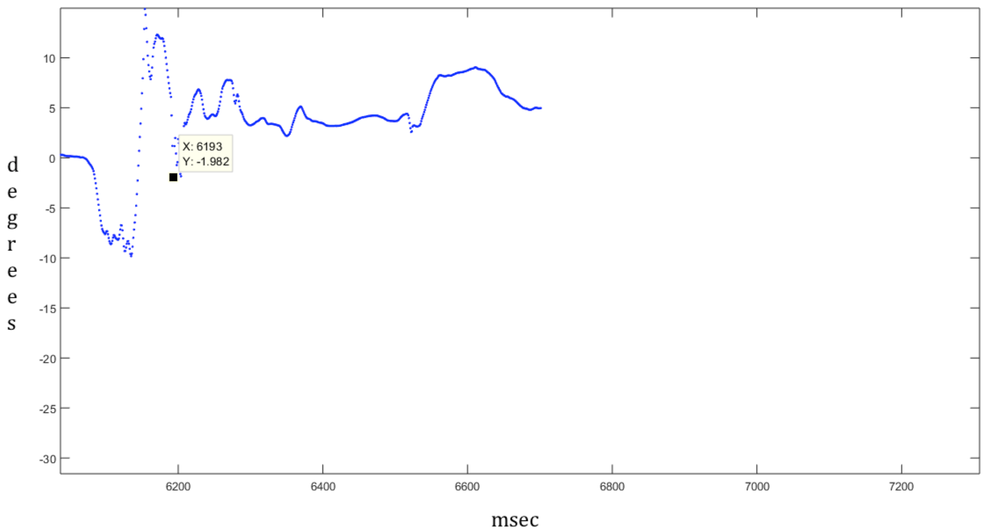
Population

The sample consists of 60 subjects aged between 8.3 and 12.6 years (mean-age=10.52, SD=1.10). Males and females have been assessed together, because in this age-band they still play basketball together, and there are no gender differences during the training and in the games.

RESULTS

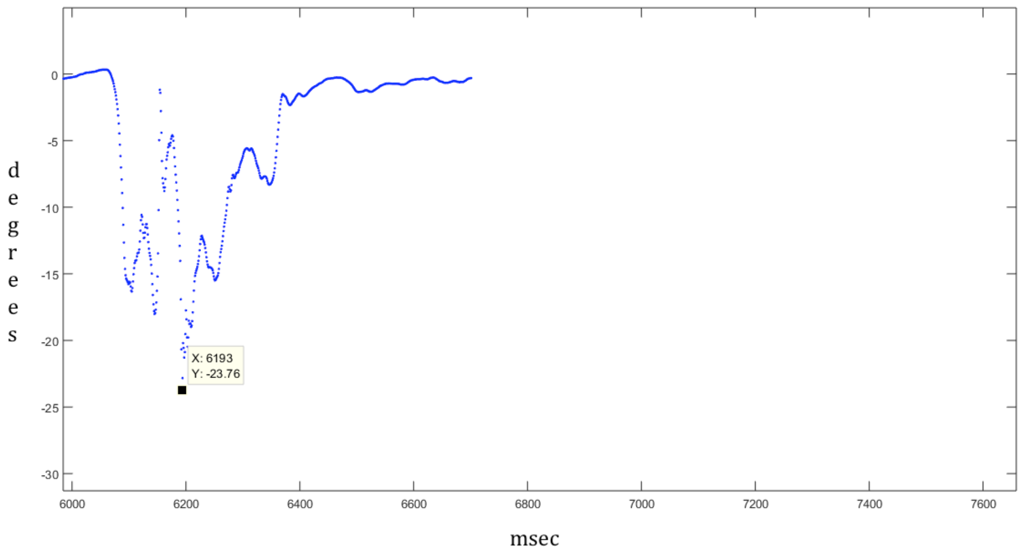
The present study refers to 60 children; in fact, the following data summarize the entire sample. Anyway I provide one randomly chosen example about the specific assessment I afforded.
For example, the following Figure 1, 2 and 3 respectively show the hip, knee and ankle attitude during the vertical jump.

Figure 1. Example of the hip attitude during the vertical jump.



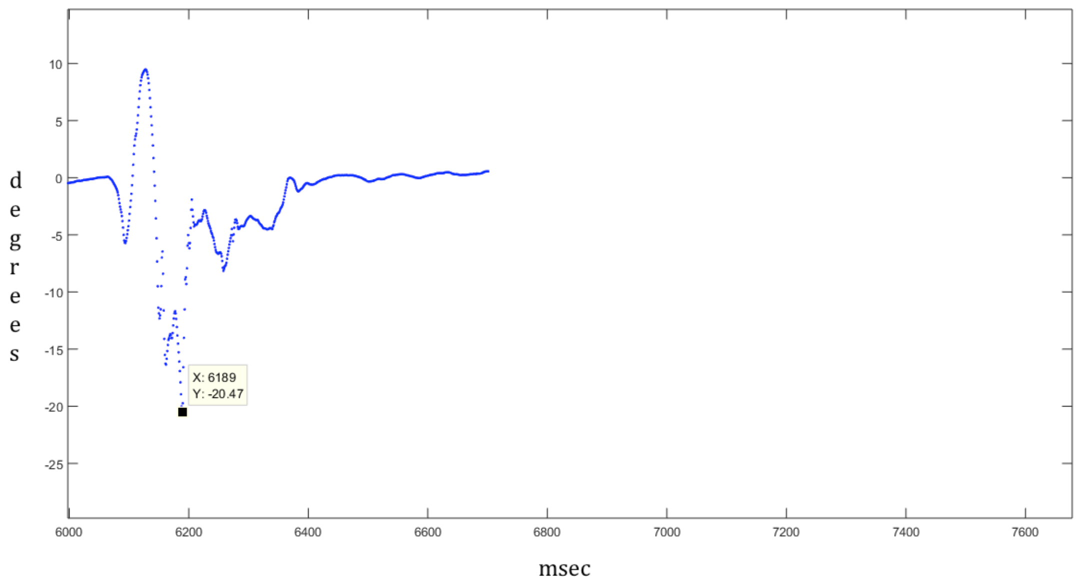
The chart expresses the attitude of the hip during all the jumping phases. It relates the range of motion (x-axis), and the timing (y-axis). The dot expresses the landing (X=6193; Y=-1.982).

Figure 2. Example of the knee attitude during the vertical jump.



The chart expresses the attitude of the knee during all the jumping phases. It relates the range of motion (x-axis), and the timing (y-axis). The dot expresses the landing (X=6193; Y=-23.76).

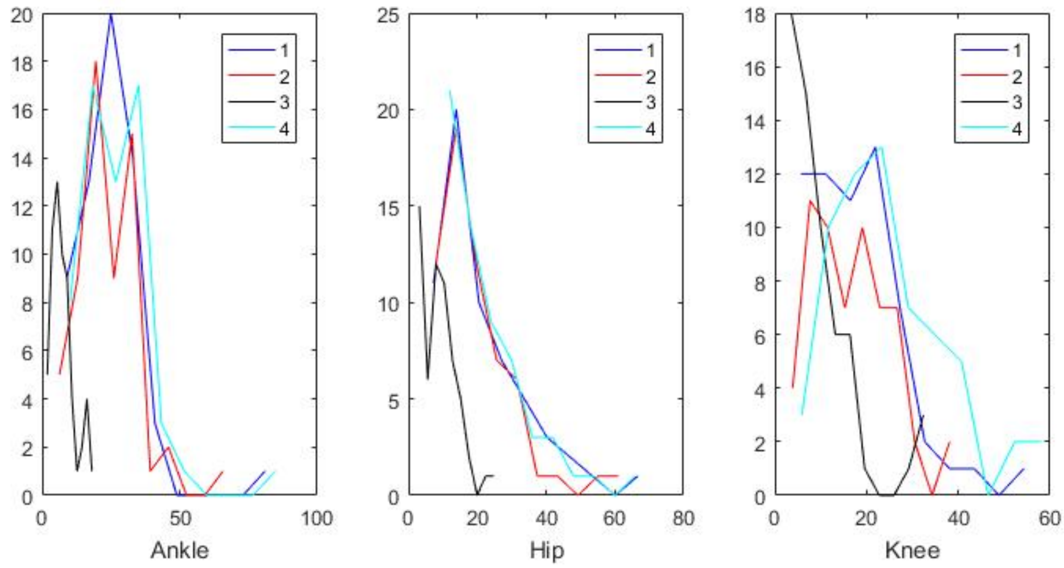
Figure 3. Example of the ankle attitude during the vertical jump.



The chart expresses the attitude of the ankle during all the jumping phases. It relates the range of motion (x-axis), and the timing (y-axis). The dot expresses the landing (X=6189; Y=-20.47).

The following Figure 4 shows the sample distribution, during the four phases of the vertical jump (down, up, flight and landing).

Figure 4. Sample distribution during the vertical jump.



x-axis=number of subjects; y-axis=degrees. 1=Blue=down phase, 2=red=up phase, 3=black=flight phase, 4=light blue=landing.

Table 2 represents a summary of the joint peak values of the same randomly chosen participant.

Table 2. Example of joint peak values.

	Start	Start-Down	Down-Up	Up-Flight	Flight-Landing
Hip	0°	-10°	1°	15°	-2°
Knee	0°	-16°	-11°	-5°	-24°
Ankle	0°	-6°	0°	10°	-21°

° Values expressed in degrees. Negative values = flexed joint position.

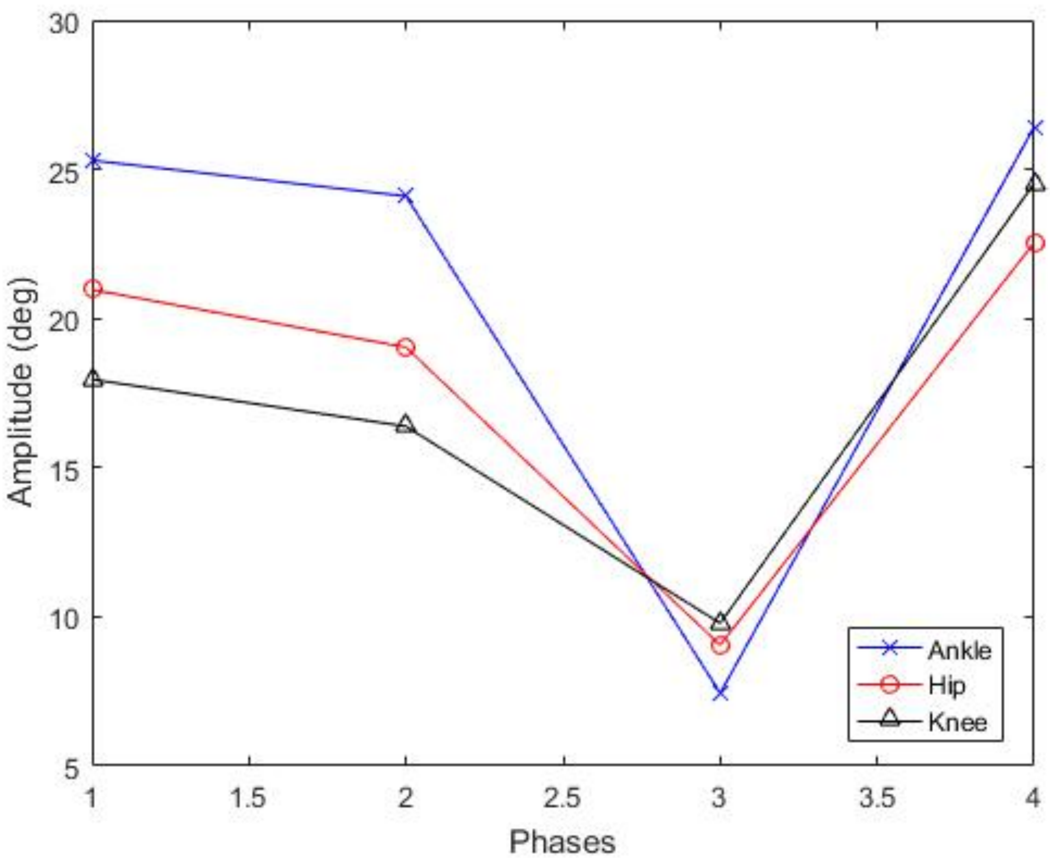
Shortly, from the starting position until the down peak (down phase), this child flexes the hip 10°; from the down peak position to the up peak (up phase), the hip produces an extension of 11°, which continues extending 14° more in the flight phase; from the flight peak to the landing, the hip makes a 17° flexion (landing phase).

From the starting position until the down peak (down phase), this child flexes the knee 16°; from the down peak position to the up peak (up phase), the hip produces an extension of 5°, which continues extending 6° more in the flight phase; from the flight peak to the landing, the hip makes a 19° flexion (landing phase).

From the starting position until the down peak (down phase), this child dorsiflexes the ankle 6°; from the down peak position to the up peak (up phase), the hip produces a plantar-flexion of 6°, which continues extending 10° more in the flight phase; from the flight peak to the landing, the hip makes a 31° dorsi-flexion (landing phase).

The following Figure 5 summarizes the mean-range of the complete sample, by considering the motion of the three joints during the vertical jump.

Figure 5. Mean-range of motion during the vertical jump.



1=down phase, 2=up phase, 3=flight phase, 4=landing phase.

The following Tables 3, 4, 5, 6 show the joints kinematics of the entire sample.
Table 3 provides the range of motion of hip, knee and ankle in the down phase.

Table 3. Joints kinematics in the down phase.

	Mean	SD	Max	Min
Hip	20.97°	13.57°	70°	4°
Knee	17.96°	10.18°	57°	3°
Ankle	25.30°	12.33°	85°	5°

° Values expressed in degrees. The data express a range of motion. Mean=mean range of motion; SD=standard deviation; Max=maximal value; Min=minimal value.

Table 4 provides the range of motion of hip, knee and ankle in the up phase.

Table 4. Joints kinematics in the up phase.

	Mean	SD	Max	Min
Hip	19.03°	11.36°	66°	5°
Knee	16.38°	8.68°	40°	2°
Ankle	24.10°	10.97°	69°	3°

° Values expressed in degrees. The data express a range of motion. Mean=mean range of motion; SD=standard deviation; Max=maximal value; Min=minimal value.

Table 5 provides the range of motion of hip, knee and ankle in the flight phase.

Table 5. Joints kinematics in the flight phase.

	Mean	SD	Max	Min
Hip	9.05°	5.16°	26°	2°
Knee	9.78°	7.36°	34°	1°
Ankle	7.44°	4.19°	16°	3°

° Values expressed in degrees. The data express a range of motion. Mean=mean range of motion; SD=standard deviation; Max=maximal value; Min=minimal value.

Table 6 provides the range of motion of hip, knee and ankle in the landing.

Table 6. Joints kinematics in the landing.

	Mean	SD	Max	Min
Hip	22.55°	11.98°	69°	9°
Knee	24.53°	12.73°	61°	3°
Ankle	26.43°	12.53°	89°	6°

° Values expressed in degrees. The data express a range of motion. Mean=mean range of motion; SD=standard deviation; Max=maximal value; Min=minimal value.

Considering the lack of children's kinematic references about the vertical jump, the following Table 7 provide a qualitative comparison with adults' kinematic values of Bobbert[10 11 12 13] evidence. The author doesn't provide data about the range of motion between the flight peak and the landing point; for this reason, Table 7 provides a qualitative comparison of just three moments.

Table 7. Qualitative comparison between observed data (children) and Bobbert's evidence (adults).

	Hip	Knee	Ankle
Down Adults	80.21°	97.40°	85.94°
Down Children	20.97°	17.96°	25.30°
Up Adults	8.02°	22.35°	21.77°
Up Children	19.03°	16.38°	24.10°
Flight Adults	52.71°	102.56°	104.28°
Flight Children	9.05°	9.78°	7.44°

° Mean-values expressed in degrees. The data express a range of motion.

Table 8 provides the quantitative comparison between the range of motion of adults and children. I use the Student's t-test for unpaired data.

Table 8. Quantitative comparison between observed data (children) and Bobbert's evidence (adults).

	Hip	Knee	Ankle
Down	0.003	<0.001	<0.001
Up	0.044	0.285	0.003
Flight	<0.001	<0.001	0.001

The data express the p-values. All the results are statistically significant, at $p<0.05$.

Because of the software settings, this kinematic assessment doesn't provide data about the joints range of motion on other planes. In fact, it considers extension and flexion, but not the axis of joints rotation. This represents a limit of the study, because the importance of the valgus attitude of the knee in the vertical jump, especially in the basketball players[1].

DISCUSSION

The vertical jump is one of the most studied movements because of its large involvement in the sport practice. Nevertheless there is a lack of evidence about the way the children –in particular the sporty children- moves. The oldest study of Clark and Phillips[3] suggested that just the 3-years-old children jump differently from the adults. Controversially, Swartz and colleagues[4] have recently affirmed, that in general the children utilize a different jump strategy compared to the adults. The present literature focuses a lot on peak velocities, joint strategies and muscular force; anyway, there is a lack of evidence about the children's biomechanics during the vertical jump. Taking into account also the evidence of Schiltz and colleagues[5], who affirm the influence of the sport practice on the jump abilities, the present research aim to increase the knowledge about the way these children jump. In particular, I have focused on sporty children, who practice basketball. In this activity the children train their jump skills because this gesture is largely involved in this sport practice. The following paragraphs explain the outcomes I found out.

First, I comment the previous Table 7 and Table 8 to understand the importance of a child-specific biomechanics analysis. Even if the sample consists of sporty, healthy children and young adolescents, the emerged results suggest large differences compared to the adults' way to move. Both the qualitative and the quantitative analysis confirm the importance of differentiating children from adults in the assessment of the vertical jump. In fact, Table 7 shows that in the younger population, hip, knee and ankle significantly reduce the range of motion. This result is coherent with the quantitative analysis, which demonstrates that the observed and the expected data always differentiate for statistically significant p-values (Table 8). Moreover, the Figure 4 graphically shows the peculiarities of children's jump. In fact, the segments demonstrate the larger use of the ankle -in terms of range of motion- respect the other involved joints.

In particular, in the down phase (Table 3), the hip flexes 80.21° in the bibliographic adult reference, and 20.97° in the observed children sample (p-value=0.003). In this phase, the same difference exists for knee (adults=97.40°, children=17.96°; p-value<0.001) and ankle (adults=85.94°, children=25.30°; p-value<0.001). It is also necessary to highlight that, in the adults the larger range of motion belongs to the knee, on the contrary in the children to the ankle. Considering the lower quadriceps strength, and the larger flexibility (Holt and colleagues, 2009)[15] of the ankle in children, I justify this outcome. From the merging data, the observed children seem to use trunk and ankle strategies to increase the strength in the down phase.

In the up phase (Table 4), the hip extends 8.02° in the bibliographic adult reference[10 11 12 13], and 19.03° in the observed children sample (p-value=0.044). In this phase, the same difference exists for knee (adults=22.35°, children=16.38°; p-value=0.285) and ankle (adults=21.77°, children=24.10°; p-value=0.003). These data seem to be more similar considering the adult and the children results. Moreover, in this phase, children's hip and ankle move more than adults' joints. Also considering the knee, the difference is reduced respect the previous phase. Even if the data are quite similar between the two populations, these outcomes suggest a wide difference between the movement patterns. In fact, during this phase, the adults begin the extension of the body, in order to strongly complete it in the following phase. On the contrary, the children early afford the main part of the extension between the down and the up peak.

In the flight phase (Table 5), the hip extends 52.71° in the bibliographic adult reference, and 9.05° in the observed children sample (p-value<0.001). In this phase, the same difference exists for knee (adults=102.56°, children=9.78°; p-value<0.001) and ankle (adults=104.28°, children=7.44°; p-value<0.001). In this phase, the emerging p-values suggest an extremely significant difference between the adults and the children range of motion: the children complete the extension of the body; on the contrary the adults afford the largest part of the extension, in this phase. The previous data are coherent with the study of Horita and colleagues (1991)[16]; even if he considers 6-years-old children, he affirms that, compared to the adults, the children don't provide a mature pattern of movement during the preparatory and the flight phase.

In literature, there is no evidence about the adults' range of motion during the last phase: the landing. However, I provide the data about the children way to move. The hip flexes 22.55°, the knee 24.53° and the ankle dorsal-flexes 26.43. These data affirm that, in all the considered joints, during the landing phase the children flex more than in the propulsion down phase. I can explicate this outcome considering the elasticity and the muscular attitude of the children. In fact, the outcomes suggest that they are unable to amortise the charge of the jump with the muscle strength, so they reach large extension ranges, especially with the flexible ankle.

CONCLUSION

The main aim of this study was to investigate the way of moving of the young basketball players. I chose a commonly used gesture for them. In order to increase the evidence about the jump biomechanics of a sporty children population, I chose the vertical jump. The outcomes reveal many differences – respect the adults- and peculiarities in the children's way to jump. The physical and mechanical characteristics of these subjects influence their pattern of movement. The method I used to assess the children, furnishes replicable data, and consent to evaluate the children in an ecological situation –in the basketball gym. The present study provides a sustainable tool to assess the joints kinematics of the children.

These outcomes would also provide some practical implications. In fact, this kind of assessment could suggest that coaches, trainers and educators would take into account the differences between children and adults, during the activities. In terms of motor learning, before teaching a specific sport gesture or movement, these figures should consider these children's motor peculiarities. This suggestion comes from a critical point of view about the early high-sport specialization of the children. For instance, in the basketball practice the jump is largely used[17 18]; by training this gesture, the coaches should remember that they're training children, with a specific motor pattern, almost completely different from the adults one. Before starting teaching complex specialized action, like the jumping shoot, the coaches should take into account how a child can jump, and how it can learn to.

Furthermore, in terms of prevention of injuries and rehabilitation, these data are also necessary to well understand the best way to help a young athlete. The large works of the ankle and the particular activation of the hip are examples of important aspects to consider in prevention and in a rehabilitation program. The inability to provide a mature pattern for the preparatory and the flight phase is also a necessary result to take into account.

To verify the influence of the basketball practice on this pattern of the jump, in the future I would like to provide this kind of data for children who are not practising sport, or who are practising other activities.

This study has permitted to deeply explore the way the sporty children develop their motor ability in this age-range. Nevertheless, their way to move also depends on important aspects, which I’m going to consider in the next Chapter.

BIBLIOGRAPHY

[1] Leppänen, M., Pasanen, K., Kujala, U. M., Vasankari, T., Kannus, P., Äyrämö, S., ... & Parkkari, J. (2017). Stiff landings are associated with increased ACL injury risk in young female basketball and floorball players. *The American journal of sports medicine*, *45*(2), 386-393.

[2] Bates, N. A., Ford, K. R., Myer, G. D., & Hewett, T. E. (2013). Kinetic and kinematic differences between first and second landings of a drop vertical jump task: implications for injury risk assessments. *Clinical biomechanics*, *28*(4), 459-466.

[3] Clark, J. E., Phillips, S. J., & Petersen, R. (1989). Developmental stability in jumping. *Developmental Psychology*, *25*(6), 929.

[4] Swartz, E. E., Decoster, L. C., Russell, P. J., & Croce, R. V. (2005). Effects of developmental stage and sex on lower extremity kinematics and vertical ground reaction forces during landing. *Journal of athletic training*, *40*(1), 9.

[5] Schiltz, M., Lehance, C., Maquet, D., Bury, T., Crielaard, J. M., & Croisier, J. L. (2009). Explosive strength imbalances in professional basketball players. *Journal of Athletic Training*, *44*(1), 39-47.

[6] Meylan, C. M., Cronin, J. B., Oliver, J. L., Hughes, M. G., & McMaster, D. (2012). The reliability of jump kinematics and kinetics in children of different maturity status. *The Journal of Strength & Conditioning Research*, *26*(4), 1015-1026.

[7] Earl, J. E., Monteiro, S. K., & Snyder, K. R. (2007). Differences in lower extremity kinematics between a bilateral drop-vertical jump and a single-leg step-down. *journal of orthopaedic & sports physical therapy*, *37*(5), 245-252.

[8] Bobbert, M. F., Gerritsen, K. G., Litjens, M. C., & Van Soest, A. J. (1996). Why is countermovement jump height greater than squat jump height?. *Medicine and science in sports and exercise*, *28*, 1402-1412.

[9] McGinnis, P. M. (2013). *Biomechanics of sport and exercise*. Human Kinetics.

[10] Bobbert, M. F., Casius, L. R., & Kistemaker, D. A. (2013). Humans make near-optimal adjustments of control to initial body configuration in vertical squat jumping. *Neuroscience*, *237*, 232-242.

[11] Bobbert, M. F., & Van Soest, A. J. (1994). Effects of muscle strengthening on vertical jump height: a simulation study. *Medicine and science in sports and exercise*, *26*(8), 1012-1020.

[12] Bobbert, M. F. (2001). Why do people jump the way they do?. *Exercise and sport sciences reviews*, *29*(3), 95-102.

[13] Bobbert, M. (2001). Dependence of human squat jump performance on the series elastic compliance of the triceps surae: a simulation study. *Journal of Experimental Biology*, *204*(3), 533-542.

[14] Al-Amri, M., Nicholas, K., Button, K., Sparkes, V., Sheeran, L., & Davies, J. L. (2018). Inertial Measurement Units for Clinical Movement Analysis: Reliability and Concurrent Validity. *Sensors*, *18*(3), 719.

[15] Holt, L. E., Pelham, T. E., & Holt, J. (2009). *Flexibility: A Concise Guide: To Conditioning, Performance Enhancement, Injury Prevention, and Rehabilitation*. Springer Science & Business Media.

[16] Horita, T. O. M. O. K. I., Kitamura, K., & Kohno, N. (1991). Body configuration and joint moment analysis during standing long jump in 6-yr-old children and adult males. *Medicine and science in sports and exercise*, *23*(9), 1068-1072.

[17] Struzik, A., Pietraszewski, B., & Zawadzki, J. (2014). Biomechanical analysis of the jump shot in basketball. *Journal of human kinetics*, *42*(1), 73-79.

[18] Oudejans, R. R., van de Langenberg, R. W., & Hutter, R. V. (2002). Aiming at a far target under different viewing conditions: Visual control in basketball jump shooting. *Human movement science*, *21*(4), 457-480.

6. CORRELATIONS BETWEEN MOTOR AND COGNITIVE SKILLS: A BIVARIATE REGRESSION ANALYSIS

The present chapter derives from a different point of view respect the previous studies. In fact, in this part, I consider the importance of the cognitive aspects in the motor development of the sporty, TD children. The posture, height and weight, and the joints range of motion during a task are individual constraints, necessary to understand physical limits and expectations of each child. On the contrary, the cognitive aspects permit to investigate how overcoming these limits, by increasing the expectations. The cognitive development is a ground-variable of the motor development, and enriches it.

In this study I propose a bivariate regression analysis, whom preliminary data have been published in the paper "Relation between Motor and Cognitive Skills in Italian Basketball Players Aged between 7 and 10 Years Old", in the Open Access Journal "Sports"[1]. In this section, I focus on cognitive and motor individual constraints, to verify the correlation between them. Through this investigation, I would like to support the involvement of cognitive aspects in each part of the motor development of the children, even if depending on teachers, coaches and educators.

INTRODUCTION

In the present literature, the correlation between physical, motor and cognitive aspects in the development of children is widely considered[2 3 4]. Many studies take into account children's developmental impairments, like the Developmental Coordination Disorders (DCD)[5 6]. For instance, in the Canadian PHAST project[7], the author investigates about the impact of motor problems on physical activity of children, and its related physical consequences on health.
Moreover, evidence demonstrates that the motor coordination of children is linked to the acquisition and to the automation of a new motor or cognitive skills[8 9 10]; furthermore, children with highly developed motor skills, seem to fulfill easily each kind of motor-and-spatial-linked cognitive task[11 12]. In fact, in some cases, the motor deficits can arise from a developmental deficit in the

executive functions[13]. These functions incorporate all the necessary complex cognitive processes, in order to perform new or difficult goal-directed tasks, like[14]: the ability to inhibit or delay a particular response, the ability to develop a plan of action sequences, the ability to hold a mental representation of the task through working memory[6 15]. In other words, the attention shift, inhibition, planning, working memory, and emotional regulation unavoidably take part in performing new or difficult goal-directed tasks. For instance, several children with DCD demonstrate scores below the average in cognitive tasks[16], which involve visuo-spatial skills, in particular in the domain of working memory; other DCD children demonstrate poor inhibitory skills, and poor performance in planning and monitoring tasks[2 3 4]. A recent review[17] takes into account the best methods for improving executive functions, and it considers physical activity, like for instance basketball.

In the Italian context there are few investigations of this topic, for both DCD and Typically Developing (TD) children. Only preliminary normative data exist, which differ from other European country children outcomes.

In the present study, my purpose is assessing a TD sporty sample, in order to identify the motor and the cognitive skills of these children. I have chosen this particular sample, because of its peculiarities. This is a preliminary work, which would like to identify the level of cognitive and motor skills, by considering also the relations between these variables. Before suggesting implications for the children with motor disorders, I consider as necessary to understand the TD children behavior; moreover, I have assessed a sporty sample –which plays basketball at a competitive level-, as example of motor trained children. Furthermore, I take into account the vocational training of the basketball coaches, in order to identify their purposes by coaching these children.

Because of the tactic and the strategic skills of basketball, as active game, I have chosen this sport to study the relations between cognitive function and motor performance[18 19] (Budde, et al., 2008; Pesce, et al., 2009). Basketball is regarded as one of the most popular sports worldwide. A considerable number of players start practicing basketball as early as 5–6 years of age. In the United States of America (USA), the National Basketball Association and the USA Basketball league created the "Youth Basketball Guidelines" (2017)[20], which aimed to promote the physical health of players; to develop age- and stage-appropriate skills; and to foster the development of peer relationships, self-esteem and leadership qualities. These guidelines provide age-appropriate standards that follow the maturation of children. The guidelines focus on the game structure (i.e., game length, timeouts), the tactics (i.e., how to set the defence) and the rules (i.e., how to manage substitutions). In 2012 in Italy, the basketball association (Federazione Italiana Pallacanestro) involves more than 300,000 coaches, players and young players[21]. In fact, basketball is the second most popular sport after soccer.

Italian basketball coaches for young players complete two-year vocational training before transitioning to practice. During this training period, the focus is largely placed on the physical, social and emotional development of the participating children[22]. Their training needs to include adequate consideration of the aerobic resistance, motor abilities and socio-emotional development of the children[23]. There have been suggestions that training should also engage cognition. For instance, the coaches should incorporate problem-solving games in order to try to foster imaginative processes[24] and develop timing and spacing abilities in their players. In any case, there is a lack of knowledge and specific information that is required for encouraging the cognitive development of these young children during basketball training.

Considering the importance of cognitive abilities in motor learning, this lack of knowledge on cognitive skills could have an impact on training. Newell's Theory of Constraints[4 25] provides a complete framework for the correlation between cognitive and motor abilities. The type of task, the environment and the capabilities of the individual player influence the motor performance. For instance, the quality of a jump depends on the environmental constraints (i.e., the surface type, the environmental stability), on the task demand (i.e., to jump beyond an object, one/two legs) and on personal characteristics (i.e., strength, cognition, sensitivity). Through this model, Newell demonstrated the reciprocal integration that exists between the dynamic motor and cognitive systems. There is evidence that supports this integration, which was obtained from both healthy[3 26] and clinical samples[2 6]. Focusing on motor control, Coker[27] provided an example of this integration in basketball practice. In fact, motion and cognition can collaborate as an integrated system to provide the motor control of the gestures. Motor control focuses on the neural, physical and behavioural aspects that are necessary to produce the correct movements[28]. In basketball practice, these systems are required to refine and re-learn motor-skills, such as intercepting a ball at the correct time or improving the landing biomechanics to prevent injuries. Prerequisite abilities, such as control precision, multi-limb coordination, rate control, aiming and catching, timing control and dynamic flexibilities, are necessary for learning basketball. In this sense, cognitive and motor systems can be integrated to guarantee the best possible motor performance.

Taking into account the importance of a keen consideration of the cognitive aspects during basketball learning and practice, in this section I analyse both cognitive and motor skills, and their relation in a sporty sample.

MATERIALS AND METHODS

Procedure

First, the project was sent to and accepted by the Ethic Committee of the University of Trieste. Following ethical approval, four basketball clubs in the region of Trieste (Italy) were invited to participate in this project. The data were collected and shared with the clubs to assess the development of the young players. A total of 82 parents gave their written informed consent to let their children participate in this study. These parents also filled an anamnestic questionnaire about the health status and the development of the child.

The participants were assessed during training in an ecological situation, but in a quiet and reserved part of the gym. Testing was conducted in two 30–45 min sessions for each child. For each subject, the sessions were both completed in two months, which were always conducted by the same operator. This study started on January 2016 and ended on February 2017. Testing was randomised in order to eliminate order-related biases.

The participants showed interest in the project and were motivated.

Participants

A total of 82 (59 boys and 23 girls) children have been recruited. They are between 7.23 and 10.99 years old (mean = 9.36, SD = 0.98, median = 9.44).

The inclusion criteria are: being aged 7–10.99 years old, and playing basketball for at least the last two years. These children are playing basketball in mean since 2.8 years (SD=0.85). Furthermore, the participants are practicing basketball two or three times per week, at a competitive level. The basketball activity is not linked to the school program and there are no academic penalties if the children do not participate.

Measures

To assess motor and cognitive skills, the following neuropsychological tests had been used. Each test provides specific instructions to be administered in the correct manner, which allow us to create trials with different controls.

In order to provide a complete assessment of cognitive and motor skills, the proposed tasks are at different difficulty levels, which are useful in characterising healthy and sporty children.

● Movement Assessment Battery for Children—2 (MABC-2)[29].

The MABC-2 is a standardised test that is used to assess the motor skills of children with movement difficulties in the following domains: Manual dexterity (MD), aiming and catching (AC) and balance (Bal). Cluster and total standard scores for Italian children are provided[30], with higher scores demonstrating better performance. A total test score at or below the 5th percentile indicates significant movement difficulty, while a score between the 5th and 15th percentile indicates that a child is “at risk”.

In these tests, the items and the scores were compared to the normative data of the uploaded version of the Italian MABC-2.

● Attention, Inhibition and Switching Assessment from the Neuropsychological Assessment—2 (NEPSY-II)[31].

This test is included in the “Attention and Executive Functioning” domain. It requires each participant to look at a series of black and white shapes or arrows and name the shape, the direction or an alternate response depending on the colour of the shape or arrow. The subtests of denomination, inhibition and switching provide information about the accuracy of the sample in terms of timing and errors made when completing the tests. A comparison between the plots that show the relationship between time and errors is not possible as many scores were 0.

In these tests, the items and the scores were compared to the normative data of the uploaded version of the Italian NEPSY-II.

- Manual Motor Sequences Assessment (MMSA) from NEPSY-II[31].

This test is included in the "Sensorimotor" domain. "Manual Motor Sequences" requires each participant to imitate and repeat a series of hand movements performed by the examiner. This counts the number of the manual sequences that participants can replicate.

In this test, the items and the scores were compared to the normative data of the uploaded version of the Italian NEPSY-II.

- Corsi's Test—Sequential Spatial Task[32].

This test assesses visuo-spatial short-term working memory. Each participant should imitate the examiner who taps a sequence of up to nine identical spatially separated blocks. Each participant should also be able to repeat this tapping sequence backwards. In this study I provide the forward (Corsi FW) and the backward test (Corsi BW).

Statistical Analysis

I provide the statistical analysis using Matrix Laboratory®. First, the sample had been compared to the normative data given by the tests in a qualitative and in a quantitative way, whenever possible.

For the MABC-2 and its subtests, I provide the standard scores, and not the percentiles[29] [30]. Thus, there were no comparisons made using *p*-values but qualitative considerations were undertaken, which were related to the incidence of motor deficits. For the three attention tasks[31], qualitative suggestions are

provided due to the structure of the given standardised data, which consider the accuracy in terms of time and error relations. For MMSA and for the Corsi's Test[31], it was possible to obtain a quantitative comparison.
Second, the scores obtained by the participants have been used to provide a bivariate regression analysis, in order to understand the correlations between motor tasks (dependent variables) and cognitive ones (independent variables).

All the chosen tests are internationally validated and used. They are age-standardized; in fact, the regression analysis doesn't involve the age, as variable. Furthermore, they have also been adapted and standardised for the Italian population. The differences found between the countries highlight the importance in considering the cultural variables. For this reason, the standard population given by the tests allowed comparison with the subjects of the study.

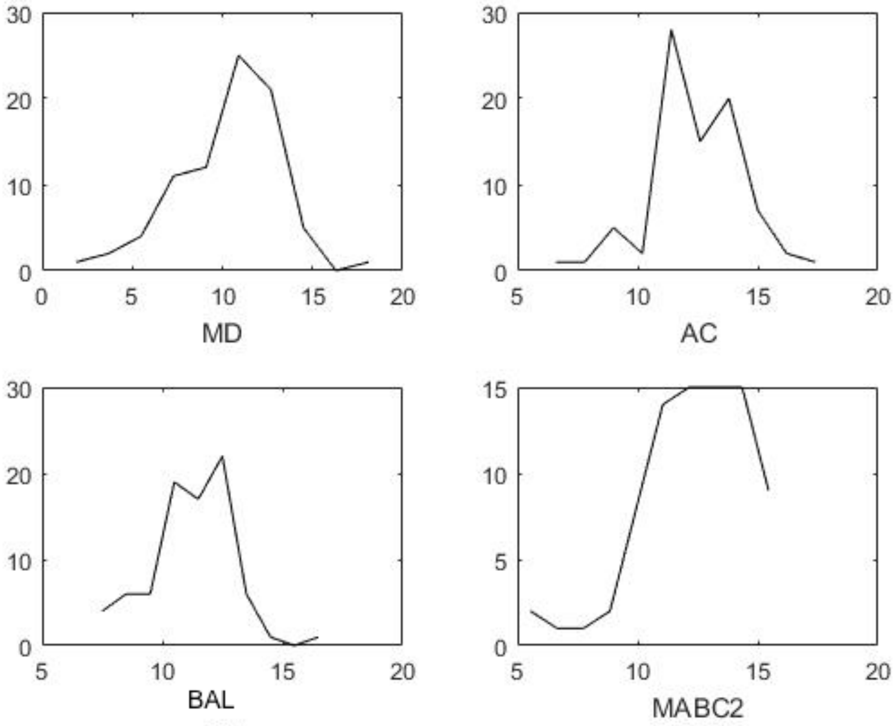
Comparing the sample to a standard expected normative Italian population could partially reduce the limitations of not having a control group. This study aims to collect data about Italian TD sporty children, in order to obtain preliminary data about their motor and cognitive development, and the existing correlations.

RESULTS

3.1. Data Analysis and Description

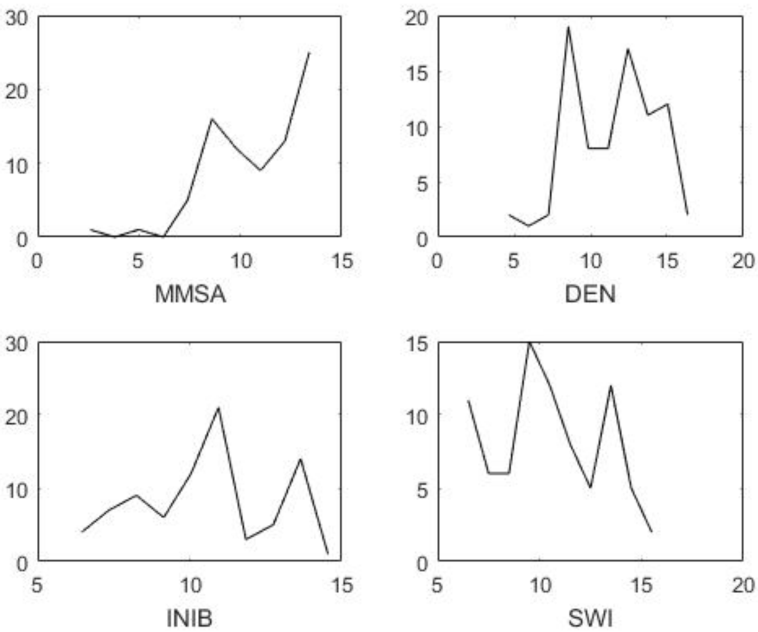
The following Figures 1, 2, and 3 show the distributions of the sample, considering the motor and the cognitive assessment.

Figure 1. Sample distribution for the motor test (Manual Dexterity, Aiming & Catching, Balance, total score of MABC-2).



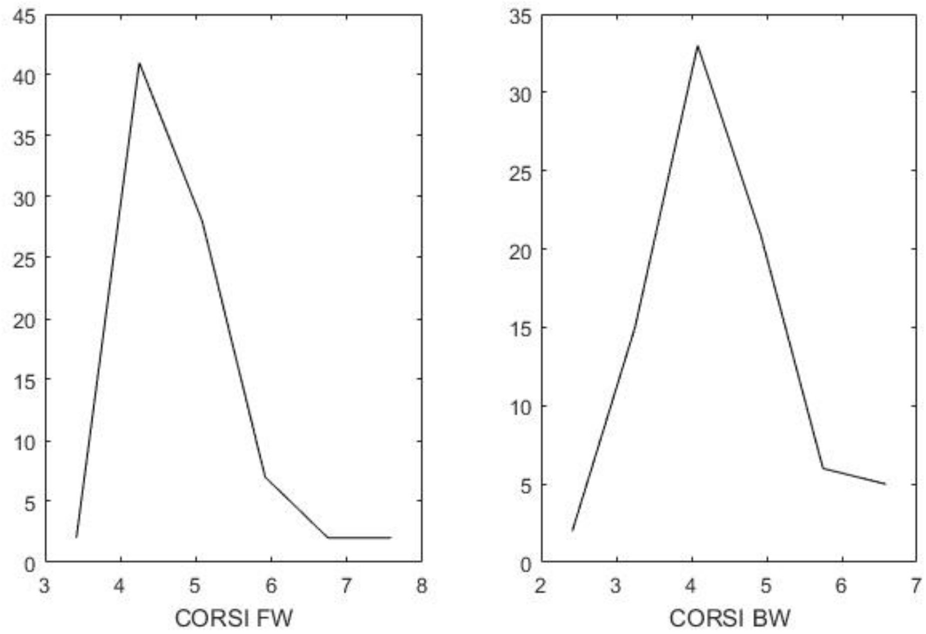
x-axis=number of subjects; y-axis=score.

Figure 2. Sample distribution for the NEPSY-ii subtest (Motor Manual Sequences Assessment, Denomination, Inhibition, Switching).



x-axis=number of subjects; y-axis=score.

Figure 3. Sample distribution for the Corsi's Test (Forward and Backward).



x-axis=number of subjects; y-axis=score.

Table 1 shows the means, the standard deviations, the ranges and the expected values for the considered variables.

The following statistical analysis provides a qualitative and –whenever possible- a quantitative analysis.

For the study of the qualitative parameters, I used the comparison between expected and observed data through tables' comparisons. The quantity of zeros in the Table for NEPSY-II Attention tests suggested to only deducing the percentage, in which the present sample ranks higher than the expected.

When possible (for MMSA, Corsi FW and Corsi BW), I provide the quantitative analysis through the *t*-test.

Table 1. Means, SDs and ranges of score for the study variables.

Test	Mean	Median	SD	Range
MABC-2	12.2	12	2.1	5–16
MD	10.5	11	2.7	1-19
AC	12.6	13	1.9	6-18
Bal	11.7	12	1.7	7-17
Denomination	11.4	12	2.8	4–17
Inhibition	10.5	11	2.4	6–15
Switching	10.9	11	2.7	6–16
MMSA	10.9	11	2.3	2–14
Corsi Front	4.7	4	0.9	3-8
Corsi Back	4.4	4	1.1	2–7

MABC-2=total score of Movement Assessment Battery for Children-2; MD=manual dexterity; AC=aiming and catching; Bal=Balance; MMSA=motor manual sequences assessment. All the scores are age-standardised.

The sample ranks in a large range of scores, for all the items of MABC-2. The Aiming & Catching skill presents the highest standard score (12.6), whether the Manual Dexterity the lowest (10.5). The Aiming & Catching score influences the total outcome of MABC-2 (12.2).

In NEPSY-II attention sub-tests (where only the qualitative analysis were possible), it is important to highlight that the majority of the observed sample ranks higher in each subtest, compared to the standard population (59% in denomination, 60% in inhibition and 64% in switching).

In NEPSY-II MMSA test, through the *t*-test, the sample demonstrates statistically significant higher scores compared to the standard population provided by the test, with a *p*-value<0.01 (standard population: mean-score = 10, SD=3).

In Corsi FW, the mean-score of the sample is 4.7 (SD=0.9), with a normal range of 3–8 points. In Corsi BW, the mean-score of the sample is 4.4 (SD=1.1), with a normal range of 2–7 points. The standardised score depends on the age of the child, and it changes for every year. A brief stratification of ages and the *t*-test scores (see Tables 2 and 3) demonstrate, that significant differences between the sample and the normal population exist (significance at p<0.05).

Table 2. Stratification for ages of Corsi FW

Age	Mean	SD	Expected Mean	*t*-Value	*p*-Value	*n*
10 years	4.58	0.83	5.03	0.92	0.18	24
9 years	4.52	0.71	4.94	-4.75	<0.01*	25
8 years	4.81	1.11	4.66	-4.84	<0.01*	27
7 years	4.83	1.47	4.34	-1.98	0.04*	6

*significant *p*-values, at p<0.05.

In Corsi FW, there are no differences between the sample and the normative data for 10-years-old children (p-value=0.18). The 9-years-old children of the present sample rank lower than the normative population, with a significant difference (p-value<0.01). 7-and-8-years-old children rank higher than the normative population, with significant differences (7-years-old-p-value=0.04; 8-years-old-p-value<0.01).

Table 3. Stratification for ages of Corsi Back.

Age	Mean	SD	Expected Mean	*t*-Value	*p*-Value	*n*
10 years	4.25	0.99	4.37	-4.54	<0.01*	24
9 years	4.52	1.23	4.35	-4.48	<0.01*	25
8 years	4.30	1.17	4.22	-4.39	<0.01*	27
7 years	4.33	1.21	4.03	0.89	0.20	6

*significant *p*-values, at p<0.05.

In Corsi Back, there are no differences between the sample and the normative data for the 7-years-old children (p-value=0.20). In the other age-bands, the children score higher than the normative population, except the 10 years-old children (p-values<0.01).

By considering the children's behaviour during the assessment, the uninterested attitude of the older children -who underestimated the difficulty of the test- could be an explanation for these results.

Bivariate Regression Analysis

Table 4 contains all the pairs of variables, which show a determination coefficient (R^2) of at least 0.05. This kind of coefficient supports the existence of at least a weak correlation between the variables. Taking into account the existing literature, I considered the motor tasks as dependent variables (MABC-2 items and MMSA), and the cognitive tasks (attention and working memory tasks), as independent ones.

At the end of this document, I provide the Attachment 1, with the complete bivariate regression analysis.

Table 3. Significant results from the bivariate regression analysis.

DV	IV	Bs	Bi	p-value	R^2
MD	Denomination	0.239	7.717	0.023	0.062
MABC-2	Denomination	0.206	9.836	0.010	0.079
MMSA	Inhibition	0.353	7.226	0.001	0.142

DV = dependent variable; IV = independent variable; Bs = Beta slope; Bi = Beta intercept; R^2 = determination coefficient.

DISCUSSION

The first aim of this study was to analyse the motor and the cognitive abilities in a TD, sporty sample of Italian young basketball players.

The statistical analysis seems suggesting the hypothesis, that the basketball practice could influence the motor skills of the children. In fact, Aiming and Catching skill is the most developed in this sample (score=12.6), compared to the Balance (score=11.7) and the Manual Dexterity (score=10.5). In fact, very early the young basketball players exercise their abilities with the ball.

By considering the cognitive outcomes, there are some differences between the items. In the attention sub-tests (where only the qualitative analysis were possible), more than half sample demonstrates to score higher than the normative sample (denomination 59%, inhibition 62%, switching 62%). These data suggest, that basketball playing might produce an indirect effect to some aspects of the executive functions. In the MMSA, the sample score significantly higher than the normative data (t-test, p-value<0.01); it seems an easy task for these subjects. The ability to imitate motor manual sequencing might not require

a large readiness to act, as well as the online control of the action. Moreover, this test requires the children to imitate an action, and not to produce a completely new one. By considering the more difficult tasks, that these children normally perform, their scores statistically differ from the standard population.
The Corsi's Test demonstrates that the results differentiate for age. In fact, in the Forward subtest, for the older children (10 years old) there are no statistical differences between the normative and the sample outcome (p-value=0.18). At the Backward subtest, the same children score lower than the expected outcome (p-value<0.01). In the other age-bands, both in the Forward and in the Backward subtest, the sample scores higher (p-values<0.01), or at the same level (p-value= 0.20) of the normative data, with no significant differences. During the assessment, I noticed that the 10-years-old children seemed uninterested in this activity, and overestimated the task: this behaviour could have influenced their performance. These data support the importance of the self-awareness of 10-years old children[33]. Like the teachers do, also the coaches and the educators could support the self-assessment and the self-consciousness, by considering the processes involved in those tasks. For this age-band, the enrolment of metacognition process seems necessary, in order to reach the expected aims.

This first part of the statistical analysis permits to understand that the cognitive skills of this TD sporty sample are in general well developed. Generally, some differences between the considered sample and the normative population (given by the tests) exist. These partial preliminary data are not so consistent to affirm, that the basketball practice influences the cognitive development; anyway I want to highlight one more time, that many children of this sample demonstrate high developing cognitive skills.

The second aim of this study was to identify the correlations between executive functions and motor abilities in this specific sample.
These data are preliminary, in order to orientate my future study about these topics; for this reason, I discuss these correlations, even if they were weak or moderate. According to the previous evidence, five positive correlations emerge. In literature, attention is strictly related to the motor development[12 18].In this sample, the total score of the MABC-2 correlates to the Denomination subtest of attention (R^2=0.055). The research of Roebers and colleagues[8] demonstrates the

involvement of attention on the development of the motor skills. The Manual Dexterity task shows the same correlation of MABC-2 to the denomination subtest (R^2=0.062). These motor tasks include a measure of speed and accuracy in each hand separately, a timed bi-manual task, an untimed drawing task and the reception and shooting tasks[28], which all require important attention prerequisites.

The MMSA correlates to the inhibition task (R^2=0.142); this outcome supports the impact of attention on the motor plan to choose. By considering the request of this task to copy a bimanual configuration, the MMSA strongly involves the sensorimotor competences. In fact, the imitation ability needs a mature sensorimotor integration, also managed by the inhibition function[27]. In particular, for a basketball sample, the correlation between MMSA and Inhibition is important, because of the needing of hands inhibitory control during the imitation, in all the learning phases.

The previous evidence supports the emerged correlations. This specific sample reveals as correlations, which are strictly involved in the motor building. The physiological explications of these correlations come from the shared neural mechanisms, between frontal cortical areas and cerebellum processes[13 34 35].

Taking into account the Corsi's test results, the working memory doesn't show correlations to the MABC-2 skills. According to the previous literature[2], the importance of the working memory in the motor action is undoubted. Nevertheless, for this specific sample, the correlations don't emerge. An explanation of this outcome could be due to the uninterested attitudes of the older children in the WM evaluation.

CONCLUSION

The beginning goal of this study was to assess a TD sporty sample, in order to identify motor and cognitive skills, but also the interaction between these abilities. I have chosen this sample, because of the peculiarities of the sport they are practicing. In a social context, where the children are at risk of sedentariness, a sporty sample represents a group of active and trained children: for my purposes, both the physical and the cognitive training are important.

By considering this sample, I have tried to analyze as deeper as possible the level of motor competence and some executive functions skill. In literature there is evidence about the correlation between cognitive and motor development, but it is focused on not-TD children. I have decided to develop this study, in order to enrich the literature about TD and sporty children, but also to understand how to be useful to help their development. In fact, the correlations implicate, for instance, that the coaches could consider also cognitive aspects in training. For instance, the basketball players frequently utilise their denomination skills when they focus on the number and the position of the player that they are defending. Attention is a necessary executive function for developing correct movement strategies and inhibiting unwanted movement. The players utilise their ability to imitate motor manual sequences every time they are learning a manual task by imitating the coach, such as during the ball-handling practice. Basketball practice is also based on visuo-spatial structures, which are used to create and improve complex motor tasks, thus creating "automatic" movements to play. For instance, players use their visuo-spatial working-memory when they learn how to dribble around opponents and when they recall this and other complex automated motor plans during the game. The previous examples would like to highlight how motor and cognitive systems are integrated to guarantee complex controlled motor performance, also in a specific sample of TD sporty children[7].

The emerged correlations, which especially highlight the connection between attention and motor tasks –in particular Manual Dexterity tasks-, support the importance of integrating this aspect, during the motor and sport activity. In order to help these sporty children to improve their skills, this could be a new learning starting point.

These are preliminary data, which highlight the impact of the cognitive aspects in the motor development. Through these results, I suppose that a cognitive-centred training could positively impact on these sporty children. The introduction of cognitive-aware tasks during training could facilitate motor learning itself.

Through this work, I'm continuing my research about the integration of different disciplines and constraints, in order to understand the development of the children, both TD and not-TD.

In the future, it could be useful to increase the sample size to confirm the present correlations and to verify whether there is a corresponding increase in their magnitude. It could also be interesting to create and validate a practical training proposal, which would involve training of the executive functions, especially attention.

Anyway, another suggestion naturally arrives: could an integrated motor-cognitive approach during the activity (or the sport practice) help the motor development of children, who show motor difficulties?

BIBLIOGRAPHY

[1] Policastro, F., Accardo, A., Marcovich, R., Pelamatti, G., & Zoia, S. (2018). Relation between Motor and Cognitive Skills in Italian Basketball Players Aged between 7 and 10 Years Old. *Sports*, *6*(3), 80.

[2] Alloway TP, Temple KJ. (2007) A comparison of working memory skills and learning in children with developmental coordination disorder and moderate learning difficulties. Appl Cogn Psychl; 21: 473-87.

[3] Piek JP, Dawson L, Smith LM, Gasson N. (2008) The role of early fine and gross motor development on later motor and cognitive ability. Hum mov scie; 27(5): 668-681.

[4] Niederer I, Kriemler S, Gut J, Hartmann T, Schindler C, Barral J, Puder JJ. (2011) Relationship of aerobic fitness and motor skills with memory and attention in preschoolers (Ballabeina): a cross-sectional and longitudinal study. BMC pediatrics; 11(1): 34.

[5] Johnson, D. C., & Wade, M. G. (2009). Children at risk for developmental coordination disorder: Judgement of changes in action capabilities. *Developmental Medicine & Child Neurology*, *51*(5), 397-403.

[6] Piek JP, Dyck MJ, Francis M, Conwell A. (2007) Working memory, processing speed, and set-shifting in children with developmental coordination disorder and attention-deficit–hyperactivity disorder. Develop Med & Child Neurology; 49(9): 678-683.

[7] Cairney, J. (Ed.). (2015). *Developmental coordination disorder and its consequences*. University of Toronto Press.

[8] Roebers, C.M.; Kauer, M. Motor and cognitive control in a normative sample of 7-years-olds. Dev. Sci. 2009,12, 175–181.

[9] Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: a meta-analysis. *Pediatric exercise science*, *15*(3), 243-256.

[10] Livesey, D., Keen, J., Rouse, J., & White, F. (2006). The relationship between measures of executive function, motor performance and externalising behaviour in 5-and 6-year-old children. *Human Movement Science*, *25*(1), 50-64.

[11] Michel, E., Roethlisberger, M., Neuenschwander, R., & Roebers, C. M. (2011). Development of cognitive skills in children with motor coordination impairments at 12-month follow-up. *Child Neuropsychology*, *17*(2), 151-172.

[12] Piek, J. P., Dyck, M. J., Nieman, A., Anderson, M., Hay, D., Smith, L. M., ... & Hallmayer, J. (2004). The relationship between motor coordination, executive functioning and attention in school aged children. *Archives of clinical Neuropsychology*, *19*(8), 1063-1076.

[13] Wilson, P. H., Smits-Engelsman, B., Caeyenberghs, K., Steenbergen, B., Sugden, D., Clark, J., ... & Blank, R. (2017). Cognitive and neuroimaging findings in developmental coordination disorder: new insights from a systematic review of recent research. *Developmental Medicine & Child Neurology*, *59*(11), 1117-1129.

[14] Hughes C, Graham A. (2004) Executive functions in childhood: Development and disorder. In J. Oates & A. Grayson (Eds.), Cognitive and language development in children (pp. 207-228). Oxford, England: Blackwell.

[15] Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental neuropsychology*, *7*(2), 131-149.

[16] Visser, J. (2003). Developmental coordination disorder: a review of research on subtypes and comorbidities. *Human movement science*, *22*(4-5), 479-493.

[17] Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental cognitive neuroscience*, *18*, 34-48.

[18] Budde, H., Voelcker-Rehage, C., Pietraßyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience letters*, *441*(2), 219-223.

[19] Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity*, *2*(1), 16-22.

[20] National Basketball Association, USA Basketball. (2017). Youth Basketball Guidelines. Retrieved: July 2nd, 2018. From https://youthguidelines.nba.com.

[21] Federazione Italiana Pallacanestro. (2012). Statistiche tesserati a livello nazionale e regionale. Retrieved: July 2nd, 2018. From http://www.fip.it/trentinoaltoadige/DocumentoDett.asp?IDDocumento=51818.

[22] Mondoni M, Avanzino R. (2014). Manuale di pallacanestro. Tecnica e didattica. Vita e pensiero. ISBN:8834324994, 9788834324998.

[23] Cremonini M, Pellegrino FM. (2010). Minibasket. L'emozione, la scoperta, il gioco. Federazione Italiana Pallacanestro.

[24] Cremonini M. (2002) Le favole nel minibasket. Retrieved: July 2nd, 2018. From http://www.basketservice.it/AREA%20TECNICA/MINIBASKET/MBD070.pdf.

[25] Newell, K. M. (1985). Coordination, control and skill. In Advances in Psychology (Vol. 27, pp. 295-317). North-Holland.

[27] Coker, C. A. (2017). *Motor learning and control for practitioners*. Routledge.

[28] Rosenbaum, D. A. (2009). *Human motor control*. Academic press.

[29] Henderson, S.E.; Sugden, D.A.; Barnett, A.L. Movement Assessment Battery for Children-2; Harcourt Assessment, Psychological Corporation: London, UK, 2007.

[30] Biancotto, M.; Guicciardi, M.; Pelamatti, G.M.; Santamaria, T.; Zoia, S. Movement Assessment Battery for Children, 2nd ed.; Giunti O.S. Psychometrics: Firenze, Italy, 2016; ISBN 978-88-09-9942-B.

[31] Korkman, M.; Kirk, U.; Kemp, S.L. NEPSY: A Developmental Neuropsycological Assessment, 2nd ed.; The Psychological Corporation: San Antonio, TX, USA, 2007.

[32] Mammarella, I.C.; Toso, C.; Pazzaglia, F.; Cornoldi, C. BVS-Corsi. Batteria per la Valutazione Della Memoria Visiva e Spaziale; Con CD-ROM; Edizioni Erickson: Trento, Italia, 2008.

[33] Sobel, D. M., & Letourneau, S. M. (2015). Children's developing understanding of what and how they learn. *Journal of experimental child psychology*, *132*, 221-229.

[34] Diamond, A. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. Child Dev. 2000, 71, 44–56.

[35] Best, J.R. Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. Dev. Rev. 2010, 30, 331–351.

7. INVESTIGATING THE CORRELATION BETWEEN EXECUTIVE FUNCTIONS AND A JUMPING TASK IN YOUNG BASKETBALL PLAYERS: A BIVARIATE REGRESSION ANALYSIS

In this chapter, I would integrate the previous cognitive and motor outcomes. In fact, I am proposing the assessment of the correlations between cognitive tasks and a particular motor skill; I chose the vertical jump, as specific gesture, continuously used by the young basketball players. The assessed executive functions are the attention and the visuo-spatial working memory.
The unexpected outcomes reveal important implications about the ability to move of this peculiar sample of young basketball players.

INTRODUCTION

The correlation between the motor and cognitive abilities in the sport practice is well established. For instance Pesce and colleagues (2009)[1] demonstrated the effects of the exercise on free-recall memory tasks. Ellemberg and Deschênes (2010)[2] affirmed the existence of a correlation between a 30 minutes aerobic exercise session and the improvement in cognitive performances, even if not permanent. Also Luz and colleagues (2014)[3] support the impact of motor skills in high complexity cognitive tasks. More recently, Bisagno and Morra (2015)[4] have assessed the development of the Working Memory (WM) related to the expertise and to the motor learning in young volleyball players of different ages. Moreover, Yumisaca and colleagues (2018)[5] focused on the importance of the attention in a specific basketball task for pre-juvenile players. Otherwise from other studies, these authors completely focus on a specific sport practice, which needs a specific motor learning. Through this kind of analysis, they investigated about the correlations between some specific executive function, and a motor task.

In the last decades, the investigation about these correlations is large, especially for not-typically developing children. For instance, Fong and colleagues (2016) [6] demonstrate, that children suffering Developmental Coordination Disorder (DCD) score lower than their peers in attention tasks. Because of an emerged correlation between motor tasks and WM, Zierieis and

Jansen (2016)[7] suggest that a specific motor training could improve executive functioning in children suffering Attention-Deficit Hyperactivity Disorder (ADHD). These are just few examples, about a deeply investigated topic. Nevertheless, for the typically developing children, evidence is inadequate to establish these correlations. The recent review of van der Vels and colleagues (2015) [8] suggest, that there is insufficient evidence for, or against, many correlations between motor and cognitive skills. The authors find out some weak-to-strong relations, and suggest deepening the researches, in order to get evidence for these correlations. Westendorp and colleagues (2014)[9] supported the concept, that the intervention in the motor domain may support the development of the cognitive one, and vice versa. For this, they suggest to deepen this topic.

In this study, I would like to interpret the previous outcomes of my research project, in order to better understand the developmental peculiarities of young basketball players. Consistent with the evidence, I have chosen to assess the attention and the visuo-spatial working memory, because of their role in the motor planning.

In the previous Chapter 6, I found out just a few correlations between motor and cognitive tasks for a young basketball players' sample (manual dexterity and general motor score to attention and motor manual sequencing). In this part of the research, I want to investigate the existence of some correlations, by changing the proposed motor task. For this, I have assessed a basketball players' typical gesture: the vertical jump.

Large evidence about the jumping exists in the literature. According to the aim of this study, I am going to focus on the outcomes of the correct pattern of the jump. In fact, I am going to consider the activation strategy of the joints, as an outcome measure to verify the validity of the chosen motor program, during the preparatory phase (McGinnis, 2013[10]). Bobbert and colleagues[11] [12] [13] [14] assessed 10 proficient male volleyball players, well-trained in the execution of the vertical countermovement jump. The author found out a proximal to distal flexion pattern during the preparatory phase, and a proximal to distal extension pattern during the propulsion phase, in order to increase the acceleration of the body. Mackala (2013)[15] also affirms that the efficacy of the vertical jump depends on the muscles activation order. For instance, in the propulsion phase, the proximal to distal extension strategy follows this order: first activation of trunk muscles (trunk extension), activation of gluteus (hip extension), activation of the quadriceps (knee extension) and final activation the gastrocnemius (ankle plantar-flexion).

Considering the previous studies (Chapter 6), in this work I'm considering a more difficult, but sport-related, gesture. In fact, I have assessed young basketball players, who largely utilize their jumping skills during the sport practice. I focus on the executive functions outcomes, and I refer to the correct joints activation pattern of the jump. In conclusion, the purpose is determining whether the investigated cognitive skills and the ability to reproduce a sport specific gesture -like the vertical jump- are related.

MATERIALS AND METHODS

First, the Ethics Committee of the University of Trieste approved this project. Two basketball Clubs guaranteed their participation in the study. The parents and the children read and signed the informed consent, and the acceptance module to participate in the study. After the written consent I immediately collected the anamnestic data. The inclusion criteria for this study were: to be aged between 8 and 12 years old, and to practice basketball at least 3 times for week from at least 2 years.

Procedures

The assessments took place in a calm and quiet place in the basketball gym, during the basketball training. According to the coaches, one player was out from the game to be assessed. To avoid the time-biases, a shorter period than a month always passes between the assessment of the executive functions and the analysis of the jump. Through the digital technology Mtw Awinda Development kit-ii®, I assessed the kinematics of the vertical jump. The previous literature supports the reliability of this assessment technology[16].

The examination of the jump required three trials. After each jump, there were pauses of 30". The feet position to start the jump had been freely chosen by each child, and I registered it on the floor with a tape. I applied the sensors on the

dominant leg in the following key-points: above to the iliac crest (lateral), 8 cm up to the knee articular line on the femur (lateral), 8 cm down to the knee articular line on the fibula on the foot (lateral), on the foot (dorsal), and on the belly button (frontal, as projection of the barycentre).
I gave the same instructions to all the participants for all the three trials, to eliminate procedures biases. I exactly asked to:

- jump as high as possible
- imagine to obstacle another player
- put the hands on the hip (to eliminate the bias of the upper limbs strength during the jump)
- land after the jump without moving, as long as possible
- follow the vocal commands.

Instruments

Mtw Awinda Development kit-ii®has been used for the assessment of the vertical jump. This is a wireless portable system of MicroElectroMechanical, which consists of accelerometers, magnetometers, gyroscopes, barometers and thermometers. The sensors are wearable and they perform a sampling frequency of 1000 Hz. To collect the data I used the MT Manager Software. This software permits to verify the real-time 3D orientation, and to assess the inertial and the magnetic forces of the sensors. During the detection of the movements, the software provide a graphic representation of the following Eulers orientation: Yaw (direction of the sensor, which rotates on the Z-axis [-180°, 180°]), Pitch (elevation and inclination of the sensor, which rotates on the Y-axis [-90°, 90°]), Roll (rotation of the sensor, which rotates on the X-axis after the second rotation [-180°, 180°]). By exporting the data in Matrix Laboratory®, I afforded the calculation to analyse the data.
In this study, I consider the activation pattern of the joints, which comes from the relative angles position. No absolute values of the limbs position have been measured and used. For this, the emerging measures don't need a previous tarature, because I'm looking for realtive values.

The assessment of the attention and the visuo-spatial working memory took place at the same conditions of the jumping assessment; it consisted of:

- Attention, Inhibition and Switching Assessment from the Neuropsychological Assessment—2 (NEPSY-II)[17].

  This test is included in the "Attention and Executive Functioning" domain. It requires each participant to look at a series of black and white shapes or arrows and name the shape, the direction or an alternate response depending on the colour of the shape or arrow. The subtests of denomination, inhibition and switching provide information about the accuracy of the sample in terms of timing and errors made when completing the tests. A comparison between the plots that show the relationship between time and errors is not possible as many scores were 0.
- Corsi's Test—Sequential Spatial Task[18].

  This test assesses visuo-spatial short-term working memory. Each participant should imitate the examiner who taps a sequence of up to nine identical spatially separated blocks. Each participant should also be able to repeat this tapping sequence backwards. In this study I provide the forward (Corsi FW) and the backward test (Corsi BW).

Population

The sample consists of 56 subjects aged between 8.44 and 12.58 years (mean-age=10.57, SD=1.04). They all have been playing basketball at a competitive level, for at least two years. Male and females have been assessed together, because in Italy in this age-band they still play basketball together, and there are no gender differences during the trainings and in the games.

Joints activation pattern of the jump

According to the previously cited literature, I assessed the joints activation pattern as an outcome measure for the jump ability. I am considering the following proximal to distal activation order indeed: hip, knee and ankle[16 21].

To convert the joints sequence into a score, I have proposed a questionnaire to 10 peers, who are working as physiotherapists for at least 3 years. Because of the literature absence of quantitative data about this topic on children, I asked them to convert the motor performance into a numeric evaluation system. They were free to choose between a 0-5, and a 1-4 scale. The following Table 1 shows in details the final most chosen evaluation system, used for my purposes.

Table 1. Joints activation pattern errors.

Sequence	Error	Score
hip, knee, ankle	none	5
hip-knee, ankle	co-activation	4
hip, ankle, knee	inversion ankle-knee	3
hip, knee-ankle	co-activation	2
ankle, knee, hip	inversion ankle-hip	2
ankle, hip, knee	complete inversion	1
knee-ankle, hip	inversion and co-activation	1
ankle, hip-knee	inversion and co-activation	1
ankle-hip, knee	inversion and co-activation	1
knee, ankle, hip	complete inversion	0
knee, hip, ankle	inversion knee-hip	0

“ , ” ordinate; “ - ” simultaneous. Score in absolute value.

RESULTS

The Table 2 shows the results of the assessment.

For the visuo-spatial working memory, the Corsi’s Test consists of two trials: the repetition of the sequence forward and backward. This test has a normal range of 2–8 points. For the attention, there are three investigated aspects: denomination, inhibition and switching. These subtests have a normal range of 1-19 points. Like previously explained, the vertical jump scores in a range of 0-5 points.

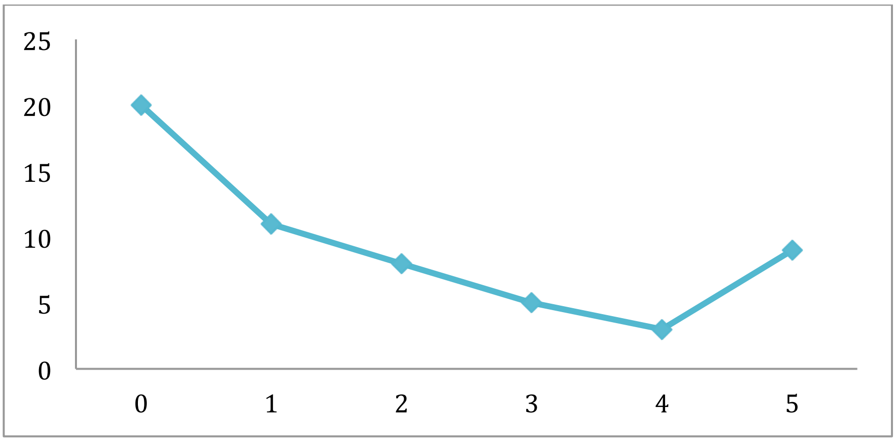
Table 2. Results of executive functions assessment.

	Corsi FW	Corsi BW	Denomination	Inhibition	Switching	Vertical jump
Mean	4.93	4.51	11.48	10.75	10.96	1.77
SD	0.96	1.04	2.82	2.61	2.90	1.84
Max	8	7	17	15	19	5
Min	3	3	4	6	6	0

FW=forward, BW=backward.

The following Figure 1 shows the distribution of the sample in the vertical jump performance.

Figure 1. Sample distribution in the vertical jump.



x-axis=umber of subjects; y-axis=score (0-5).

I provide a bivariate regression analysis, considering the cognitive outcomes are always considered as an independent variable, and the joints activation score as a dependent one.

Table 3 summarizes the outcomes of this analysis.

Table 3. Bivariate regression analysis between jump performance and cognitive outcomes.

	Corsi FW	Corsi BW	Denomination	Inhibition	Switching
Bs	-0.03	-0.04	-0.19	0.19	-0.14
Bi	3.05	4.56	11.81	10.42	11.21
R^2	0.02	0.01	0.01	0.02	0.01

Bs = Beta slope; Bi = Beta intercept; R^2 = determination coefficient.

By considering the weakness of the determination coefficients, I don't provide more details about these calculations. The outcomes demonstrate no correlations between the investigated executive functions and the jump performance.

DISCUSSION

According to the literature suggestions, this study focuses on the possible correlation between cognitive and motor abilities in a young sporty sample. Taking into account the evidence of Bisagno and colleagues (2015)[3], I have referred to young basketball players, who have been practising basketball at a competitive level, for at least two years. I have chosen a specific motor task, in order to provide a more specific assessment for the sporty children.

I have proposed an investigation of the correlation between the attention, the working memory, and the vertical jump ability. According to the literature, I decided to consider a well-known movement, usually used by basketball players during their activity (Heishman and coll., 2018[19]; Rojas and coll., 2000[20]). I consider the jump like a task of normal difficulty, because in the basketball practice these children face several more complex, rapid and coordinated motor tasks.

The outcomes demonstrate, that the expected correlations don't exist (Table3).

There are different possible explanations, in order to justify this result.

First, the big gap between the good cognitive scores and the inappropriate motor performance, could affect the expectations. In fact, in all the cognitive tests, the sample scores on average higher than the median value (Table 2). On the contrary (Figure 1), the 70% of the children (39 on 56) ranks in the lower scores of the chosen range (0-2). Even if I consider the vertical jump a well-known, basketball—related gesture, just 9 children (16.07% of the participants) activate their joints following the correct joints pattern (score 5; Figure 1). This result is surprising. In most cases, the assessed young basketball players commit heavy errors during the jumping preparation phase.

Second, in order to deeply analyse the results, I also refer to the literature comparison between typically developing (TD) and not-typically developing children. Literature suggests, that children with DCD utilize more motor control strategies, than the TD peers[21 22]. Their motor difficulties require the DCD children to efficiently control their movements; through this on-line control they can guarantee a better performance (especially in fine motor tasks)[23]. On the contrary, the TD children are probably more self-confident with their bodies and their movements; for this, they less control their body, and use automatic strategies. Normally, the lack of control is higher with the increasing of the speed of the task. Nevertheless, even if in this vertical jump I asked them to prepare the jump as good as possible, the sample committed several errors in the activation of the joints. I suppose that, the assessed children have used an automatic –but incorrect- pattern of movement. The jumping results provide the evidence of an insufficient on-line motor control during the task. Normally, this automatic strategy is efficient; in this case, a more precise motor plan would have helped them, to avoid errors. These outcomes seem suggest, that, in this sample, the motor learning of the vertical jump is not mature, and could need more self control during the performance.

By considering the expected correlations, most literature supports this outcome[24 25]. Best (2010) [26] suggests that balance and agility/strength tasks have a lower cognitive demand, than fine motor performance; they require less cognitive engagement, which justifies the absence of cognitive correlations to the vertical jump. In addition, Rigoli and Piek (2012)[27] also affirm, that the working memory skills is only linked to aiming and catching skills –even if in an older adolescent sample.

CONCLUSION

The present study denies the existence of a correlation between the executive functions and the vertical jump, but it provides more interesting implications.

Children, who have been practising basketball three times for a week, for at least two years, are considered sporty. They train to increase their strength and their force, to improve their strategic and tactical skills, to play, and win the games. According to the present outcomes, considering the ability to jump, I suppose that the coaches focus their attention on the quantitative aspects of the motor performance, such as the speed of running, or the jumping height. The results support a lack of reflexing moments, in which the players could concentrate on their own body, activate on-line motor control, in order to refine the motor learning of a specific gesture. This activity, necessary to learn a new motor task, is probably entirely dedicated to the specific basketball gestures, like the shoot and the pass. I suppose that the coaches consider the general motor abilities as already well settled; the present outcomes deny this conviction. The assessed young basketball players demonstrate, that a large part of the sample hasn't learned how to jump, following the correct pattern. The analysis of an automatic sequence of movement like the jump, and the consciousness about the emerging errors are necessary to improve the motor abilities.

This study one more time supports the importance of a cognitive approach for older and younger players, necessary in order to correctly automate the general and sport-specific abilities. In this particular case, the first step is the understanding of the correct joints sequence to jump, during a calm and reflexing exercise. Then the children should embody the movement and practising it in a protected situation –not during a game–.

Even if my beginning purpose was to verify a correlation between the motor and cognitive abilities, the implications of the present outcomes are deeper and more worrying: the activation of an incorrect motor program could affect the motor performance, and the consequent motor development (Rizzolatti and Sinigaglia, 2006)[28]. On the contrary, providing the correct joints pattern could impact on the motor learning, and facilitate more difficult tasks. Furthermore, using a correct sequence of movement could be useful in order to prevent injuries.

BIBLIOGRAPHY

[1] Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity*, *2*(1), 16-22.

[2] Ellemberg, D., & St-Louis-Deschênes, M. (2010). The effect of acute physical exercise on cognitive function during development. *Psychology of Sport and Exercise*, *11*(2), 122-126.

[3] Luz, C., Rodrigues, L. P., & Cordovil, R. (2015). The relationship between motor coordination and executive functions in 4th grade children. *European Journal of Developmental Psychology*, *12*(2), 129-141.

[4] Bisagno, E., & Morra, S. (2015). Analysis of the Relation between M-Capacity Development, Expertise and Motor Learning in Young Volleyball Players. In *EAPCogSci*.

[5] Yumisaca, O. A. O., Cruz, G. T. O., Garnica, J. P. R., Gómez, M. F. M., & Riera, M. P. B. (2018). Influence of attention on the effectiveness in free throws of pre-juvenile basketball team. *Lecturas: Educación Física y Deportes*, *23*(239), 39-48.

[6] Fong, S. S., Chung, J. W., Cheng, Y. T., Yam, T. T., Chiu, H. C., Fong, D. Y., ... & Macfarlane, D. J. (2016). Attention during functional tasks is associated with motor performance in children with developmental coordination disorder: A cross-sectional study. *Medicine*, *95*(37).

[7] Ziereis, S., & Jansen, P. (2016). Correlation of motor abilities and executive functions in children with ADHD. *Applied Neuropsychology: Child*, *5*(2), 138-148.

[8] van der Fels, I. M., te Wierike, S. C., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of science and medicine in sport*, *18*(6), 697-703.

[9] Westendorp, M., Houwen, S., Hartman, E., Mombarg, R., Smith, J., & Visscher, C. (2014). Effect of a ball skill intervention on children's ball skills and cognitive functions. *Med. Sci. Sports Exerc*, *46*, 414-422.

[10] McGinnis, P. M. (2013). *Biomechanics of sport and exercise*. Human Kinetics.

[11] Bobbert, M. F., & Van Soest, A. J. (1994). Effects of muscle strengthening on vertical jump height: a simulation study. *Medicine and science in sports and exercise*, *26*(8), 1012-1020.

[12] Bobbert, M. F. (2001). Why do people jump the way they do?. *Exercise and sport sciences reviews*, *29*(3), 95-102.

[13] Bobbert, M. (2001). Dependence of human squat jump performance on the series elastic compliance of the triceps surae: a simulation study. *Journal of Experimental Biology*, *204*(3), 533-542.

[14] Bobbert, M. F., Casius, L. R., & Kistemaker, D. A. (2013). Humans make near-optimal adjustments of control to initial body configuration in vertical squat jumping. *Neuroscience*, *237*, 232-242.

[15] Mackala, K., Stodólka, J., Siemienski, A., & Coh, M. (2013). Biomechanical analysis of squat jump and countermovement jump from varying starting positions. *The Journal of Strength & Conditioning Research*, *27*(10), 2650-2661.

[16] Al-Amri, M., Nicholas, K., Button, K., Sparkes, V., Sheeran, L., & Davies, J. L. (2018). Inertial Measurement Units for Clinical Movement Analysis: Reliability and Concurrent Validity. *Sensors*, *18*(3), 719.

[17] Korkman, M.; Kirk, U.; Kemp, S.L. NEPSY: A Developmental Neuropsycological Assessment, 2nd ed.; The Psychological Corporation: San Antonio, TX, USA, 2007.

[18] Mammarella, I.C.; Toso, C.; Pazzaglia, F.; Cornoldi, C. BVS-Corsi. Batteria per la Valutazione Della Memoria Visiva e Spaziale; Con CD-ROM; Edizioni Erickson: Trento, Italia, 2008.

[19] Heishman, A. D., Miller, R. M., Freitas, E. D., Kaur, J., Galletti, B. A., Koziol, K. J., & Bemben, M. G. (2018). Countermovement Jump Reliability when Performed With and Without an Arm Swing in Ncaa Division 1 Basketball Players: 2748 Board# 31 June 1 2. *Medicine & Science in Sports & Exercise*, *50*(5S), 669.

[20] Rojas, F. J., Cepero, M., Oña, A., & Gutierrez, M. (2000). Kinematic adjustments in the basketball jump shot against an opponent. *Ergonomics*, *43*(10), 1651-1660.

[21] Biotteau, M., Chaix, Y., Blais, M., Tallet, J., Péran, P., & Albaret, J. M. (2016). Neural signature of DCD: a critical review of MRI neuroimaging studies. *Frontiers in neurology*, *7*, 227.

[22] Schott, N., El-Rajab, I., & Klotzbier, T. (2016). Cognitive-motor interference during fine and gross motor tasks in children with Developmental Coordination Disorder (DCD). *Research in developmental disabilities*, *57*, 136-148.

[23] Zwicker, J. G., Missiuna, C., Harris, S. R., & Boyd, L. A. (2010). Brain activation of children with developmental coordination disorder is different than peers. *Pediatrics*, peds-2010.

[24] Aadland, K. N., Moe, V. F., Aadland, E., Anderssen, S. A., Resaland, G. K., & Ommundsen, Y. (2017). Relationships between physical activity, sedentary time, aerobic fitness, motor skills and executive function and academic performance in children. *Mental Health and Physical Activity*, *12*, 10-18.

[25] Wunsch, K., Pfister, R., Henning, A., Aschersleben, G., & Weigelt, M. (2016). No interrelation of motor planning and executive functions across young ages. *Frontiers in psychology*, *7*, 1031.

[26] Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review*, *30*(4), 331-351.

[27] Rigoli, D., Piek, J. P., Kane, R., & Oosterlaan, J. (2012). An examination of the relationship between motor coordination and executive functions in adolescents. *Developmental Medicine & Child Neurology*, *54*(11), 1025-1031.

[28] Rizzolatti, G., & Sinigaglia, C. (2006). *So quel che fai: il cervello che agisce ei neuroni specchio*. R. Cortina ed.

8. ANIMAL FUN: A PREVENTION MOTOR PROPOSAL FOR PRE-SCHOOLER CHILDREN

The last part of this project comes from a deep reasoning about how to help the typically developing children in their motor development. This study supports some important implications about the moment to introduce the motor learning. Soon in the early childhood, physical activity and sport involvement could be proposed. Including the motor activity in the children's habit could contribute decreasing future inactivity. Through an Australian movement program, it is possible to include the motor activity in the early childhood school programs.

INTRODUCTION

Movement is strongly related to the cognitive, physical, social and psychological development of the children. It contributes to the prevention of physical disease, like obesity or cardiovascular problem (Cairney, 2015)[1]. By participating in the social involvement of the children, motor activity contributes avoiding important internalising problems such as anxiety and depression[2]. Recent findings demonstrate anxiety and depression behaviours also in 4-5-years-old-children (Piek, 2008)[3]. Harter (1993)[4] demonstrates that the confidence in own proper motor abilities determines the child's involvement level. Not engaging a successfully level of motor skills creates a continued negative loop (Hands and colleagues, 2002)[5], where the child has low motor competences, develops low fitness training and goes to hypo-activity. On the contrary, if the children are confident with their motor skills, they participate in an activity such as sports practising, or dancing. Bart and colleagues (2007)[6] relate the motor ability of preschool children, to their scholastic adaptation and to the social adjustment in the first year of school. In fact, the preschool age-band is peculiar because the children experiment new complex movements and improve their abilities about the easier gestures[7]. They increase their ability in the ordinary well-known tasks, but they also learn new motor experiences. For instance, at 4 years of age, a child is able to climb the stairs with an alternate pattern, it is able to stand up and jump on a single leg. Moreover, during the pre-schooler age the ability of aiming and catching improve, by providing a more balanced and controlled performance. Surprisingly there is a lack of movement program to engage pre-schooler children in the motor activity. In 2010 Piek and her colleagues[8] at Curtin University have developed the "Animal Fun" movement program. The purposes of the authors were to provide appropriate activities for the children, consent to observe peers or teachers by performing the task, support the children with a verbal encouragement, reduce and eliminate competition. They have created a protocol, which engages all the children and doesn't exclude anyone (2015)[9]. By referring to all the members of a class, Animal Fun avoids the stigma associated with the "special programs". This is an ecological program, proposed in the school during the ordinary activities, like Greenberg's evidence suggests (2003)[10]. Animal Fun is an imaginative program of movement, in which the children imitate animals' movements and gestures. It is flexible and doesn't provide a rigid structure to follow, but it adapts to children abilities.[11]

In Italy the lack of a motor program for pre-schooler children is consistent. However, there are many proposals for high specific sports practices. At 4 years of age, the possibility to play basketball or soccer is just a low attempt to reproduce very complex motor tasks. Often the children of this age-band don't afford the necessary prerequisites to be able to practice a complex sport. The difficult tasks proposed in these contexts are affordable just from children with well-developed motor skills. Anyway, these young children would all benefit more from a non-specific physical activity. The needing to identify an inclusive and flexible motor program has led us to Animal Fun. Considering the socio-cultural differences between Western Australia and Italy, the purpose of this study is to verify the feasibility to propose Animal Fun to Italian pre-schooler children.

MATERIALS AND METHODS

Animal Fun

Animal Fun is an interactive, adaptable program of movement, which addresses to pre-schooler children of all the abilities level. Its aim is to promote motor and social development. It respects the evolutional phases and it considers the importance for children of enjoining the activities. 9 modules compose the program:

- Module 1: Body Management (Static Balance, dynamic Balance, Climbing)
- Module 2: Locomotion (Walking, Jumping, Hopping, Skipping)
- Module 3: Object Control (Throwing, Catching, Kicking)
- Module 4: Body Sequencing (Trunk, Limbs)
- Module 5: Body and Kinaesthetic Management – Trunk and Upper Limb (Eye-hand coordination, Visual-kinaesthetic)
- Module 6: Fine Motor Planning
- Module 7: Tool Control (Pre-scissor/scissor skills, Paintbrush use, Drawing/pre-writing skills)
- Module 8: Hand Skills (Individual finger strength, Grip strength, Pincer grip)
- Module 9: Social/Emotional Development (Laughter, Identifying and labelling feelings, Breathing, relaxation).

The gross motor modules focus on the static and dynamic balance, on the strengthening of the lower limb muscles, on the locomotion abilities (i.e. hopping, running), and on the techniques of throwing. In these modules I could propose complex movements, by combining the previously listed abilities (throwing a ball and hopping).

The fine motor modules focus on postural stability, on the strengthening of the upper limb muscles, on the correct use of objects (i.e. the scissor, the joystick).

The social/emotional module focuses on emotional discrimination and awareness.

Piek and colleagues[11] confirmed the efficacy of Animal Fun on motor performance, through a randomized controlled trial investigated, by using a multivariate nested cohort design.

Procedure

First, the Ethics Committee of the University of Trieste approved this project. I have involved in the study two schools of the city of Trieste (Italy). The parents gave their informed written consent to let the children participate.

The study develops in three different stages:

- Stage 1: first assessment of the motor abilities through the Movement Assessment Battery for Children-2 (MABC-2; Henderson et al., 2007[12]);

- Stage 2: thirty minutes of Animal Fun activity, three times a week, for one month.
- Stage 3: final assessment through MABC-2.

The activity had been proposed to the whole classes during the ordinary program of the primary school by a physiotherapist. A teacher participated and helped to manage the children, especially during the big groups activity.

Measures

- Movement Assessment Battery for Children—2 (MABC-2) [12].

  The MABC-2 is a standardised test that is used to assess the motor skills of children with movement difficulties in the following domains: Aiming and Catching (AC), Balance (Bal), and Manual Dexterity (MD). Cluster and total standard scores for Italian children are provided [16], with higher scores demonstrating better performance. A total test score at or below the 5th percentile indicates significant movement difficulty, while a score between the 5th and 15th percentile indicates that a child is “at risk”.

In these tests, the items and the scores were compared to the normative data of the uploaded version of the Italian MABC-2[13].

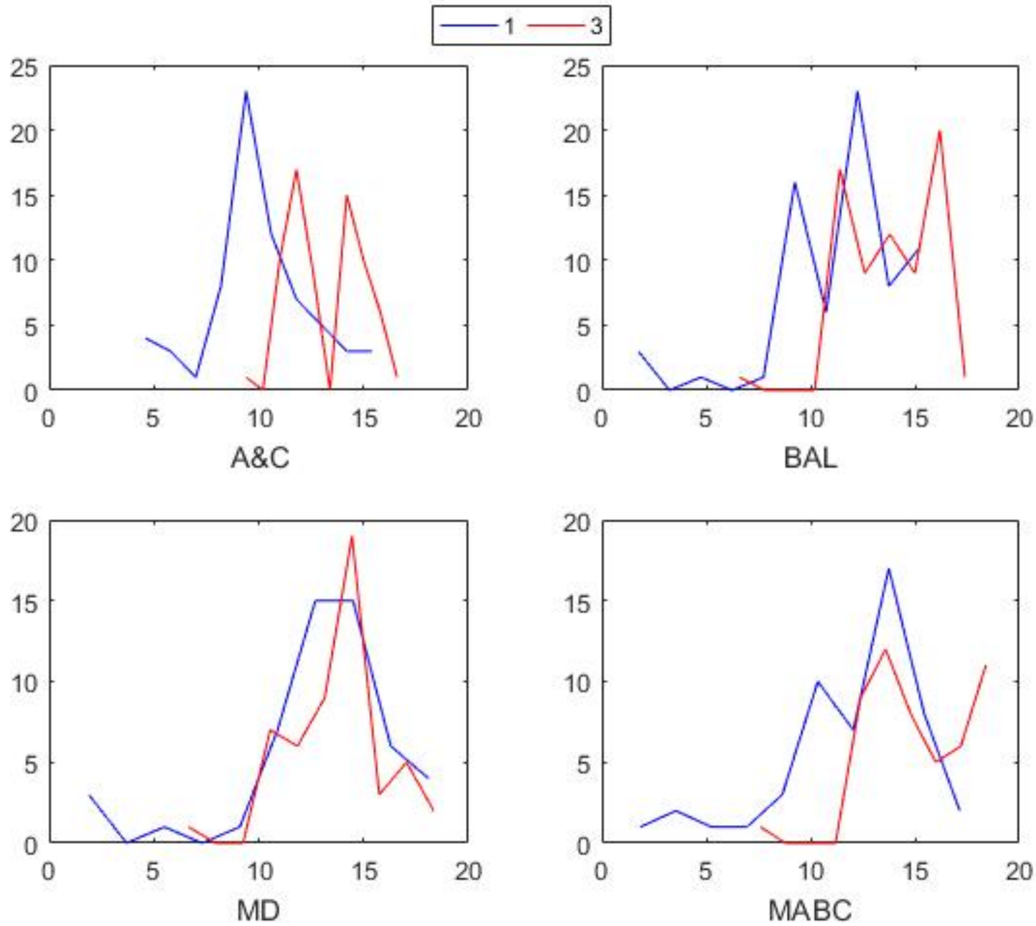
Population

The sample consists of 69 children, 35 males and 34 females (mean-age=4.79, SD=0.78, median=4.90). I assessed just 52 children (one school) for the MD cluster and the total score, because of managing reasons, linked to the collaboration of the teachers of that school.

RESULTS

Figure 1 shows the distribution of the sample in the MABC-2 tests at Stage 1 and 3.

Figure 1. Sample distribution for MABC-2 tasks.



x-axis=number of sbjects, y-axis=score. Blue line=stage, red line=stage 3.

In the following results I'm going to show the data of the whole population, but also gender and age stratifications.

The following Table 1 shows the MABC-2 scores at Stage 1. The mean-score refers to the standard score from the Italian version of MABC-2.

Table 1. Aiming & Catching, Balance, Manual Dexterity, and Total score at Stage 1 and Stage 3

	A&C S1	A&C S3	Bal S1	Bal S3	MD S1	MD S3	Tot S1	Tot S3
Mean-score	10.06^	13.23^	11.75^	13.99^	12.85^	13.75^	12.00^	15.23^
SD	2.52	1.69	3.21	1.96	3.79	2.30	3.31	2.26
Percentile	49.48°	82.61°	69.58°	87.11°	77.81°	84.47°	71.20°	92.03°
n	69	69	69	69	52	52	52	52

A&C=Aiming & Catching; Bal=Balance; MD=Manual Dexterity; Tot=Total MABC-2 score. SD=standard deviation. n=number of participants. ^ standard score expressed through absolute value. ° percentile expressed through ordinary values. S1=Stage 1; S3=Stage 3.

By considering the distribution of the sample at Stage 1, I apply the paired parametric t-test, in order to assess the motor skills after the one-month Animal Fun proposal (Table 2).

Table 2. T-test scores comparing Stage 1 and Stage 3.

	p-value	t-value
A&C	<0.00001**	-8.69
Bal	<0.00001**	-4.93
MD	0.07	-1.47
Tot	<0.00001**	-5.81

A&C=Aiming & Catching; Bal=Balance; MD=Manual Dexterity; Tot=Total MABC-2 score. t-value=t-test score. ** extremely significant score at $p<0.05$.

In order to deeply describe the changing between Stage 1 and Stage 3, I provide stratifications of the sample. The following Tables 3 and 4, separately show the outcomes of females and males at Stage 1 and Stage 3. I don't provide a cross-sectional comparison between males and females, because this analysis wouldn't fit with the purposes of the study. I aim to describe the qualitative behaviour of the two groups without comparing them.

Table 3. Aiming & Catching, Balance, Manual Dexterity, and a Total score of Females at Stage 1 and Stage 3.

	A&C S1	A&C S3	Bal S1	Bal S3	MD S1	MD S3	Tot S1	Tot S3
Mean-score	9.88^	12.56^	12.12^	14.24^	13.32^	13.61^	12.25^	15.18^
SD	2.56	1.50	2.90	1.54	3.27	1.79	2.62	1.79
Percentile	46.91°	77.76°	72.41°	89.56°	80.44°	85.09°	73.61°	93.21°
n	34	34	34	34	28	28	28	28

A&C=Aiming & Catching; Bal=Balance; MD=Manual Dexterity; Tot=Total MABC-2 score. SD=standard deviation. n=number of participants. ^ standard score expressed through absolute value. ° percentile expressed through ordinary values.

Table 4. Aiming & Catching, Balance, Manual Dexterity, and a Total score of Males at Stage 1 and Stage 3.

	A&C S1	A&C S3	Bal S1	Bal S3	MD S1	MD S3	Tot S1	Tot S3
Mean-score	10.23^	13.89^	11.40^	13.74^	12.29^	13.92^	11.71^	15.29^
SD	2.51	1.62	3.49	2.29	4.32	2.81	4.01	2.76
Percentile	51.97°	87.31°	66.83°	84.73°	74.74°	83.75°	68.40°	90.64°
n	35	35	35	35	24	24	24	24

A&C=Aiming & Catching; Bal=Balance; MD=Manual Dexterity; Tot=Total MABC-2 score. SD=standard deviation. n=number of participants. ^ standard score expressed through absolute value. ° percentile expressed through ordinary values.

In order to assess the stratified samples' behaviour between Stage 1 and Stage 3, I apply the paired t-test. The following Table 5 summarizes the outcomes of the longitudinal analysis of males and females.

Table 5. t-test scores comparing Stage 1 and Stage 3 for Females and Males separately.

	p-value	t-value
Females A&C	<0.00001**	-5.26
Females Bal	0.0002**	-3.76
Females MD	0.34	-0.41
Females Tot	<0.00001**	-4.89
Males A&C	<0.00001**	-7.24
Males Bal	0.0007**	-3.33
Males MD	0.06	-1.54
Males Tot	0.0004**	-3.61

A&C=Aiming & Catching; Bal=Balance; MD=Manual Dexterity; Tot=Total MABC-2 score. t-value=t-test score. ** extremely significant score at $p<0.05$.

I also provide stratification by age. In fact, I propose a different longitudinal analysis for children aged 3-4, and 5-6 years. The following Tables 6 and 7 separately show the outcomes of younger and older children at Stage 1 and Stage 3. I don't provide a cross-sectional study of younger and older children, because this analysis wouldn't fit with the purposes of the study. I aim to describe the qualitative behaviour of the two groups without comparing them.

Table 6. Aiming & Catching, Balance, Manual Dexterity, and a Total score of younger children at Stage 1 and Stage 3.

	A&C S1	A&C S3	Bal S1	Bal S3	MD S1	MD S3	Tot S1	Tot S3
Mean-score	9.64^	13.31^	10.67^	13.50^	12.71^	13.39^	11.11^	14.96^
SD	2.29	1.79	3.68	2.14	4.39	2.71	3.58	2.50
Percentile	46.50°	82.83°	61.84°	83.79°	75.86°	84.19°	63.54°	90.46°
n	36	36	36	36	28	28	28	28

A&C=Aiming & Catching; Bal=Balance; MD=Manual Dexterity; Tot=Total MABC-2 score. SD=standard deviation. n=number of participants. ^ standard score expressed through absolute value. ° percentile expressed through ordinary values.

Table 7. Aiming & Catching, Balance, Manual Dexterity, and a Total score of older children at Stage 1 and Stage 3.

	A&C S1	A&C S3	Bal S1	Bal S3	MD S1	MD S3	Tot S1	Tot S3
Mean-score	10.52^	13.12^	12.91^	14.52^	13.00^	13.54^	13.04^	15.54^
SD	2.71	1.60	2.24	1.60	3.02	1.74	2.66	1.96
Percentile	52.73°	82.36°	78.03°	90.73°	80.08°	84.79°	80.15°	93.85°
n	33	33	33	33	24	24	24	24

A&C=Aiming & Catching; Bal=Balance; MD=Manual Dexterity; Tot=Total MABC-2 score. SD=standard deviation. n=number of participants. ^ standard score expressed through absolute value. ° percentile expressed through ordinary values.

In order to assess the stratified samples' behaviour between Stage 1 and Stage 3, one more time I apply the paired t-test. The following Table 8 summarizes the outcomes of the longitudinal analysis of younger and older children.

Table 8. t-test scores comparing Stage 1 and Stage 3 for younger and older children separately.

	p-value	T-value
Younger A&C	<0.00001**	-7.57
Younger Bal	0.0005**	-4.13
Younger MD	0.11	-1.25
Younger Tot	0.00001**	-4.67
Older A&C	<0.00001**	-4.81
Older Bal	0.0007**	-3.35
Older MD	0.22	0.76
Older Tot	0.0003**	-3.71

A&C=Aiming & Catching; Bal=Balance; MD=Manual Dexterity; Tot=Total MABC-2 score. T-value=T-test score. ** extremely significant score at $p<0.05$.

DISCUSSION

The motor activity influences the physical, psychological, and social attitude of the children[1,2]. Bart[6], Piek[3] and other authors give consistent references about the importance of proposing physical activity to the pre-schooler children. In this study, my purpose is to promote motor activity, in order to support the motor development of the kids. Animal Fun is an Australian movement protocol, which addresses to young kids. In order to verify the feasibility of the application of Animal Fun protocol for the Italian pre-schooler children, I afford this study. The results support this hypothesis. After the one-month-long activity the participants demonstrate a statistical extremely significant improvement (Table 2) in Aiming & Catching (p-value=<0.00001), and in Balance clusters (p-value=<0.00001), but they also improve in the total MABC-2 score (p-value=<0.00001). The Manual Dexterity score doesn't demonstrate a statistically significant improvement (p-value=0.07). Anyway, the qualitative assessment demonstrates that the mean-percentile changes from the 77.81st to the 84.97th percentile, from Stage 1 and Stage3. This qualitative (Table 1) -but not quantitative- improvement could be explained taking into account the normal school activities the children do. In fact, the teachers have referred that the children usually use to play with small objects, paint, draw, or nip and tuck. On the contrary, they rarely play with the ball or practice balance games. The qualitative score at Stage 1 (Table 1) is coherent, and demonstrate that the children rank in a higher percentile in the MD (77.81st percentile) than in A&C (49.48th percentile) or Bal (69.58th percentile) cluster. I suppose that the small improvement in the MD cluster is due to a high ranking at Stage 1.

The emerging data provide suggestions considering gender and age differences in the sample.

At Stage 1 (Table 3) the females rank at the 46.91st percentile in A&C, at the 72.41st percentile in Bal, and at the 80.44th percentile in MD. In the qualitative analysis (Table 3), they improve in all the clusters (A&C 77.76th percentile; Bal 89.56th percentile; MD 85.09th percentile). Nevertheless, the improvement in the MD cluster is the only not statistically significant (p-value=0.34; Table 5). Considering the MD high ranking at Stage 1 (Table 3), I justify this outcome.

At Stage 1 (Table 4) the males rank at the 51.97th percentile in A&C, at the 66.83rd percentile in Bal, and at the 74.74th percentile in MD. In the qualitative analysis (Table 4) they also improve in all the clusters (A&C 87.31st percentile; Bal 84.73rd percentile; MD 83.75th percentile). In the quantitative analysis, the males demonstrate a statistically significant improvement, excepting in the MD cluster. Nevertheless, the p-value (0.06; Table 5) suggests that in this cluster the males improve more than the females. The higher ranking of females at Stage 1 one more time supports this suggestion. In the total MABC-2 score both groups improve with statistically significant p-values (females <0.00001; males 0.0004; Table 5). The females change from the 68.40th to the 90.64th percentile between Stage 1 and Stage 3. The males change from the 73.61st to the 93.21st percentile at the same time. Both groups strongly improve after the motor proposal.

I provide also an investigation of the age-related difference in the sample. I separate the younger (3-4 years old) and the older (5-6 years old) children. At Stage 1 (Table 6) the younger children rank at the 46.50th percentile in A&C, at the 61.84th percentile in Bal, and at the 75.86th percentile in MD. In the qualitative analysis (Table 6), they improve in all the clusters (A&C 82.83rd percentile; Bal 83.79th percentile; MD 84.19th percentile). Nevertheless, the improvement in the MD cluster is the only not statistically significant (p-value=0.11; Table 8).

The older group shows the same outcomes. At Stage 1 (Table 7) the older kids rank at the 52.73rd percentile in A&C, at the 78.03rd percentile in Bal, and at the 80.08th percentile in MD. In the qualitative analysis (Table 7), they also improve in all the clusters (A&C 82.36th percentile; Bal 90.73rd percentile; MD 84.79th percentile). The improvement in the MD cluster is the only not statistically significant for the older children too (p-value=0.22; Table 8). The groups behave in a similar way: both they improve with a statistical significant p-value in the MABC-2 total score (younger <0.00001; older 0.0003; Table 8). Moreover, the younger children change from the 64.54th to the 90.46th percentile in the MABC-2 total score, between Stage 1 and Stage 3. The older children pass from the 80.15th percentile to the 93.85th percentile. Even if all the children significantly improve, I highlight the lower ranking of the younger children at Stage 1. I suppose that this outcome is due to the smaller physical education the younger children receive. In Italy the children approach to the physical activity later. At 5-6 years of age the parents propose them to afford a sport practice. They constantly begin to attend a gym during this age-band. They start practicing a specific sport: a lack of an early general motor approach seems to exist.

CONCLUSION

The previous results seem supporting the promotion of Animal Fun in the Italian pre-school population. The consistent changes of the sample would suggest continuing investigating on this. My purpose for the immediate future is to enrich this study with a control group. If the results would be positive, I would also increase the duration of this activity, and involve more schools and more children. According to the authors of Animal Fun, the involvement of the teachers and the parents is necessary. In a social context where the children especially plays with technologic games in a static position, an enjoying involving continue motor activity is necessary; this should not be only a one-month-long proposal.

Even if the lack of a control group is a limitation of this study, this preliminary results lead to some suggestions. Normally the pre-schooler children practice a specific sport, or they completely don't afford the physical education, nor at school, neither in the gym. Sometimes someone plays in the garden with brothers and friends. Unfortunately, in general they don't live many useful situations to learn and develop the general movements and motor prerequisites. These children would enjoy and would benefit from participating in a motor program, considered as a school activity. Even if I am not providing a comparison with a control group, I can support the promotion of this kind of activity indeed.

In this study, I am not considering and assessing all the related benefits a motor program could bring (Cairney, 2013)[2]. The involvement of the children in a group motor proposal could have good consequences on their social and emotional development. They could feel more comfortable in moving with other children and they could reduce some stressing emotion, such as anxiety. The future studies address to increase the sample, to enrich the assessment, and to include a control group.

BIBLIOGRAPHY

[1] Cairney, J. (Ed.). (2015). *Developmental coordination disorder and its consequences*. University of Toronto Press.

[2] Cairney, J., Rigoli, D., & Piek, J. (2013). Developmental coordination disorder and internalizing problems in children: the environmental stress hypothesis elaborated. *Developmental Review*, *33*(3), 224-238.

[3] Piek, J. P., Bradbury, G. S., Elsley, S. C., & Tate, L. (2008). Motor coordination and social–emotional behaviour in preschool-aged children. *International Journal of Disability, Development and Education*, *55*(2), 143-151.

[4] Harter, S. (1993). Causes and consequences of low self-esteem in children and adolescents. In *Self-esteem* (pp. 87-116). Springer, Boston, MA.

[5] Hands, B.P., Parker, H., & Larkin, D. (2002). What do we really know about the constraints and enablers of physical activity levels in young children?.

[6] Bart, O., Hajami, D., & Bar-Haim, Y. (2007). Predicting school adjustment from motor abilities in kindergarten. *Infant and Child Development: An International Journal of Research and Practice*, *16*(6), 597-615.

[7] Zoia, S. (2004). *Lo sviluppo motorio del bambino*. Carocci.

[8] Piek, J. P., Straker, L. M., Jensen, L., Dender, A., Barrett, N. C., McLaren, S., ... & Bradbury, G. (2010). Rationale, design and methods for a randomised and controlled trial to evaluate" Animal Fun"-a program designed to enhance physical and mental health in young children. *BMC pediatrics*, *10*(1), 78.

[9] Piek, J. P., Kane, R., Rigoli, D., McLaren, S., Roberts, C. M., Rooney, R., ... & Straker, L. (2015). Does the Animal Fun program improve social-emotional and behavioural outcomes in children aged 4–6 years?. *Human movement science*, *43*, 155-163.

[10] Greenberg, M. T., Weissberg, R. P., O'brien, M. U., Zins, J. E., Fredericks, L., Resnik, H., & Elias, M. J. (2003). Enhancing school-based prevention and youth development through coordinated social, emotional, and academic learning. *American psychologist*, *58*(6-7), 466.

[11] Piek, J. P., McLaren, S., Kane, R., Jensen, L., Dender, A., Roberts, C., ... & Straker, L. (2013). Does the Animal Fun program improve motor performance in children aged 4–6 years?. *Human movement science*, *32*(5), 1086-1096.

[12] Henderson, S.E.; Sugden, D.A.; Barnett, A.L. Movement Assessment Battery for Children-2; Harcourt Assessment, Psychological Corporation: London, UK, 2007.

[13] Biancotto, M.; Guicciardi, M.; Pelamatti, G.M.; Santamaria, T.; Zoia, S. Movement Assessment Battery for Children, 2nd ed.; Giunti O.S. Psychometrics: Firenze, Italy, 2016; ISBN 978-88-09-9942-B.

9. CONCLUSIONS AND IMPLICATIONS

This three-year-long work has been possible thanks to the collaboration and the cooperation of Basketball Clubs and schools. Sometimes coaches and teachers notice the clumsiness and the awkwardness of their healthy, typically developing, and sporty children and players. Anyway, they don't know how to afford this problem. In fact, requesting a child to be balanced on unstable surfaces, or to shoot a ball by running, are not always easy exercises. There are many prerequisites that the child should manage before affording these tasks. Sometimes, the children are not ready and able to control their body; in order to reach the aim, they usually use motor compensation strategies. These compensation strategies emerge like clumsy and strange global movements. I am talking about children with no diagnoses of developmental disorders. However, a simple awkwardness of a child could already affect its motor and sport performance. It could influence its posture too.

As physiotherapist and basketball coach, my interest focuses on these topics for several years. In both the circumstances, my duty is to facilitate the correct movement. The main aim of this research was to be able to identify which factors are to be considered, in order to facilitate the correct movement of my young patients and players.

The results I found out allow a more complete view of the motor development of the young healthy population who practice the sport. One more time, I would highlight that part of these data are preliminary, and represent the beginning of a multidisciplinary approach to propose to educators or trainers. I choose a basketball players' sample because of the peculiarities of this sport.

At the beginning of this study, the Newell's Theory of the constraints[1] -whom I refer in this work (Chapter 2)- permitted to understand the size and the complexity of the problem. As a complex subject, the child receives several influences in its development. This theoretical framework highlights the importance to consider the problem in all its different aspects and point of view. Taking into account the environment, the subjects and the tasks variability, I have built this project research.

The first part of this study (Chapter 3) focuses on the posture, as a physical individual constraint. Considered like the way our body faces the external stimuli like gravity or instability, the posture influences our ability to move and our way to behave. This attitude influences the motor skills and impacts on the injuries, like the LBP. Anyway, evidence affirms that is rarely possible to identify a clear correlation between risky factors and LBP. Nevertheless, both sedentariness and impact sport activity[2] are relevant considering the LBP incidence. In this part of the research, I focus on the postural constraint. In fact, I had proposed an LBP prevention protocol for two consecutive basketball seasons. Having an impact on the postural attitude –as risky factor-, I aimed to help the children improving their motor abilities and basketball performances too. The prevention program focused on strengthening and stretching muscles, on balance exercises, on alignment postures. After this two-seasons program, the statistical analysis has shown a significant modification in the posture of the young players. Nevertheless, in some items, the results don't satisfy. For instance, the dynamic movements, the strengthening of gluteus and quadriceps, and the stretching, have not been sufficient to bring a modification on the valgus attitude of the knees. This outcome is worrying because of the mechanical stress that these joints are suffering, in particular during the basketball practice[3]. The lack of a control group should not permit to know what could occur without this prevention protocol. Anyway, considering the basketball-related valgus stress, I consider positive my attempt to reduce this attitude. By focusing on the reasons for this failure, I suppose that an early cognitive training is necessary. These sporty children need to understand how to move their body, in particular how to orientate their lower limbs. Through this suggestion, I afford another constraint related to the body self-perception. Without self-perception of the body position in the space, a healthy posture is not possible. In this project, for time-related reasons, I have been not able to face this problem, which should be deeply investigated.

In other items, like the lumbar-pelvic angle or the flat attitude of the feet, the prevention protocol has a relevant effect. Through this longitudinal statistical analysis, I have also evaluated the time-related changings. In fact, considering the forward attitude of the head, I suppose that there have been also a cognitive learning about the compensation strategies to avoid, and the correct posture to maintain, during the two-years program. One more time I am considering the self-perception consciousness, which makes part of another constraint item. Through this work, I have reached my main aims. In fact, the small changing in the quantitative analysis is supported by the large improvement in the qualitative assessments. I consider this study as the starting point to intervene in the motor development of the children, and to identify individual aspects to consider, in order to facilitate their motor competences.

My wide project continues focusing on another individual aspect, which could impact on the motor development of the sporty and healthy children. In fact, in the second part of this study (Chapter 4), I have assessed the possible influence of height and weight on the postural development of these children.

In the last decades, obesity is a common problem for children and adolescents[4]. Especially in the paediatric population, this increasing problem is leading to many comorbidities. Evidence supports the correlation between overweight and posture[5]. In my study, I aim to verify if in a healthy, typically developing, sporty sample there is a correlation between postural alterations and obesity. For instance, postural misalignments, knees[6] and feet abnormalities[7], the sacral inclination, and the hyperlordosis are more common in obese children and adolescents[8].

The first purpose of my work was to identify height-and-weight conditions of these sporty children, considered as active because they practice sport at a competitive level.

The final aim was to compare overweight, obese and normal-weight children, in order to give some implications about the importance of weight on postural control.

The results of this part of the study are worrying; the 16.67% of children considered sporty, active and healthy is obese or overweight. Comparing these children to the normal-weight group, quantitative and qualitative differences emerge. In fact, the obese and the overweight children demonstrate a larger forward head attitude with respect to the normal-weight ones. Furthermore, the percentage of children with postural alterations (not-physiological values) is higher in the overweight and obese group for all the items –except the lumbar-pelvic angle. By the way, I suppose that the overweight impacts on the posture, which consequently influences the motor competences.

In order to prevent injuries and to improve the motor performances of these young athletes, the excessive weight is another individual negative factor, which could affect the posture too. However, the postural attitude of the normal-weight children consists of several alterations too.

The first emerging suggestion is to deeply assess the motor activity to propose to the children. The overweight and the obese children demonstrate more posture alterations respect the normal-weight peers. The sport or motor activity they choose should not worsen these alterations, leading to muscle-skeletal diseases or injuries. I am not supporting the sedentary life, and I am not proposing some activities at the expense of others. Before starting an activity, I strongly suggest taking into account height, weight, and own postural attitude. They have to afford also an integrative corrective activity, which focuses on the physical and postural attitude. In the case of overweight and obese children, managing the nutrition is also necessary; unfortunately, this aspect is not considered in this paper.

Both the first and the second work of this project give suggestions about the management of the sporty and healthy children, in order to consider physical and postural attitudes. Even if these children are practising a sport activity, the social context in which they live continuously offers them static stimuli. The sedentary maintained postures at school, the technological devices overuse, and the static games influence their postural and motor development. In order to limit the static posture and the overweight impact, the basketball practice –or any other sport activity- can't be enough. In these high specific activities, the coaches have not the time to spend to intervene on postural needing. For this reason, the inclusion of a complete postural and motor specific program is necessary for all the children (underweight, normal-weight, overweight and obese). I suppose that providing stretching, alignment, and balance exercises the children could improve their postural attitude, even in the case of obesity or overweight. Furthermore, a list of postural-tips should be also useful to increase the self-consciousness about the postural problems.

The last pondering of this part of the research addresses to the inactive children. In fact, the previous suggestions meet both the sporty and the inactive children. The importance of the physical activity during the childhood and the adolescence is well known and undoubted. To prevent wrong postural attitudes, an active opportunity of movement is necessary. The involvement of the schools in this kind of management would be suggested.

Taking into account the little evidence about this specific sample, my main aim was to increase at most the knowledge about the peculiarities of this population. Consequently, the third part of this research has tried to explain the jump kinematics in the young basketball players.

In the third part (Chapter 5) of this research project, I have chosen the vertical jump, because of the large involvement of this gesture during the basketball practice[9]. In particular, the jump is useful to move closer to the basket, but also to reach the ball, or to throw the ball stronger. Since the early beginning of the basketball training, the young players experiment and improve their jump ability through the practice. Increasing the evidence about the jump ability of the children who are playing basketball is the aim of this particular part of the research.

I have considered the vertical jump kinematics as an outcome measure to verify the young basketball players' motor skills. Nevertheless, there is a lack of evidence about the way the children –in particular, the sporty children- moves. Some evidence suggests that the children utilize a different jump strategy compared to the adults[10], but the authors especially focus on peak velocities, joint strategies and muscular force[11]. On the contrary, I afforded the assessment of the joints kinematics of the children.

Both the qualitative and the quantitative analysis confirm the importance of differentiating children from adults in the assessment of the vertical jump. The data support large differences, probably due to the lower quadriceps strength, and the larger flexibility of the ankle in children.

The observed children seem to use trunk and ankle strategies, more than the knee activation –like the adults do. Moreover, the previous data are coherent with some reference, because the children don't provide a mature pattern of movement during the preparatory and the flight phases.

I afford the main aim, which consisted of increasing the evidence about the jump biomechanics of a sporty children population. In fact, the present study provides a sustainable tool to objectively assess the joints kinematics of the children.

In this part of the work, I am considering the importance of individual constraints, like the physical attitude and the individual motor development. Moreover, I am taking into account also the constraints produced by a specific task in a specific environment. Being largely precise, this kind of assessment permits to determine the motor behaviour of the subjects, without errors.

The practical implication suggests taking into account the differences between children and adults, by training them. Before teaching a specific sport gesture or movement, but also to prevent injuries, or to create a rehabilitation program, the professionals should consider these children's motor peculiarities. The large works of the ankle and the particular activation of the hip, are examples of important aspects to take into account in a training, prevention, or rehabilitation programs.

The fourth part (Chapter 6) of this research completes the assessment of the constraints, which influence the motor development, and focuses on the cognitive involvement.

During the basketball practice, the coaches promote physical, motor and socio-emotional development of the children. There are a few attentions to the cognition; in particular, they propose problem-solving games, foster imaginative processes, and promote timing and spacing abilities[12 13]. The Italian basketball school offers little knowledge about the cognitive ability to develop[14]. Evidence demonstrates that several cognitive systems built and refine motor skills. In this sense, cognitive and motor systems can be integrated to guarantee the best possible motor performance[15]. This suggestion involves all the motor developmental stages, not even the sporty and active children's. Anyway, this study focuses on the importance of a keen consideration of the cognitive aspects during basketball learning and practice. This peculiar approach reflects the theoretical framework, where all the individual, environmental and task constraints are considered. In order to first verify the cognitive development of this particular sample, I have assessed the children focusing on attention and memory functions. In fact, my main aim was to identify the correlations between the executive functions (attention, working memory) and the motor abilities of these young basketball players.

Especially for typically developing children, evidence about the correlations between cognitive and motor systems is a few[16]. I focus on this research to be able to highlight the relevance of cognitive development in basketball young players. The emerging outcomes have demonstrated that some positive correlations between cognitive and motor abilities exist. In particular, the attention and inhibition are involved. One more time these results support the integration between the motor and the cognitive systems, in order to guarantee the complex controlled performance. The considered executive functions provide a deeper self-knowing about the body's way to move, which could help the children in developing difficult motor tasks. I afford this kind of analysis because I stress the importance of the cognitive aspects of the sensorimotor development of these children. The identification of the executive functions related to the motor skills in such as specific sample would facilitate the motor development of these children. Focusing especially on attention and inhibition permits to build specific protocols and training programs, in order to try to optimise and enrich the training potential. The introduction of cognitive-aware tasks during the practice also facilitates the children.

In my opinion, the strength of this approach is the sport-relation I have considered. Each sport activity bases on specific executive functions to develop. Probably, soccer or volleyball players would provide another kind of correlations between the cognitive and motor abilities. For this reason, I strongly support the importance to assess the subject for all its aspects and peculiarities. In conclusion, the third part of the project suggests us continuing research on these topics, in order to compare the motor-cognitive relations in the different sport practices too. The idea to have a possible method, which could help clumsy, awkward, bur sporty children, would be a consistent issue for my future studies.

Until this point of the project I have considered many individual constraints: the postural attitude, height and weight, and the sport-related executive functions of a sample of young basketball players.

The fifth part (Chapter 7) of my research unifies some previous outcomes, in particular, the cognitive skills and the kinematics of the vertical jump. Like each motor task, during its planning and its execution, the vertical jump engages cognitive, sensori-motor, and perceptive aspects. In this part of the study, I assess which executive functions are involved in the first phase of this gesture.

According to the existing evidence[17] [18], I have assessed the possible correlations between attention, visuo-spatial working memory, and the ability to jump. I have decided to provide this analysis, in order to deepen the knowledgments about this specific sample's development and motor learning.

In other words, I aimed to verify the existence of the executive functions' correlation to a specific sport-related motor task. For this purpose, I chose the jump, in terms of correct activation of the joint movement strategy[19]. I focused on the correct jumping pattern (hip, knee, ankle), to understand whether the young players are able to correctly plan and program a sport-specific, theoretically well-known movement.

Anyway, the results deny this hypothesis; no correlations emerge.

The high scoring in the cognitive tasks and the low performance in the motor test probably altered the beginning assumptions. The assessment considered the joints activation sequences in the first phase of the vertical jump (down). The sample performed worse than the expectations.

The outcomes suggest, that the children did not correctly prepared the jump-action. Like usually tyipically developing children do for automated tasks, during the performance a lack of on-line control emerged. Because of their self-confidence with the task, they don't apply a deeper control to improve the gesture strategy. This translate into a lower performance, than the expected. By considering the vertical jump as sport-specific automated task, this sample didn't correctly learn how to perform it.

In order to explain these data, I suppose that the children are practising and improving the jump, focusing more on quantitative aspects (height and strength), than on qualitative ones (joints activation strategy).

An incorrect activation of a motor program could influence the motor learning and could affect the consequent motor performance[20].

Many other explanations support the results.

References support the diffulty to identify motor-cognitive correlations in typically developing children[6]. Some author identifies correlations only for fine motor tasks, and not for gross motor (agility-strenght) ones –like the vertical jump[21]- which require a lower cognitive involvement. Even if for an older sample, for instance, another evidence supports the unique correaltion of visuo-spatial working memeory to aiming and catching skills[22].

These young basketball players are able to train and play basketball, but a few of them can activate the correct joints at the correct timing to jump. In the basketball practice, the jump is considered as a prerequisite, in order to develop other more complex tasks. In particular the jump is a required general movement that a child early learns in its development. Anyway, the jumping learning doesn't involve only strength, resistance or height aspects. A complete and efficient motor learning also involves sensorimotor, coordinative and self-perception abilities. Not activating the correct sequence of joints during a general movement task suggests a lack of qualitative details in the specific motor program.

In the following Figure 1, I would summarize my research by focusing on the considered constraints.

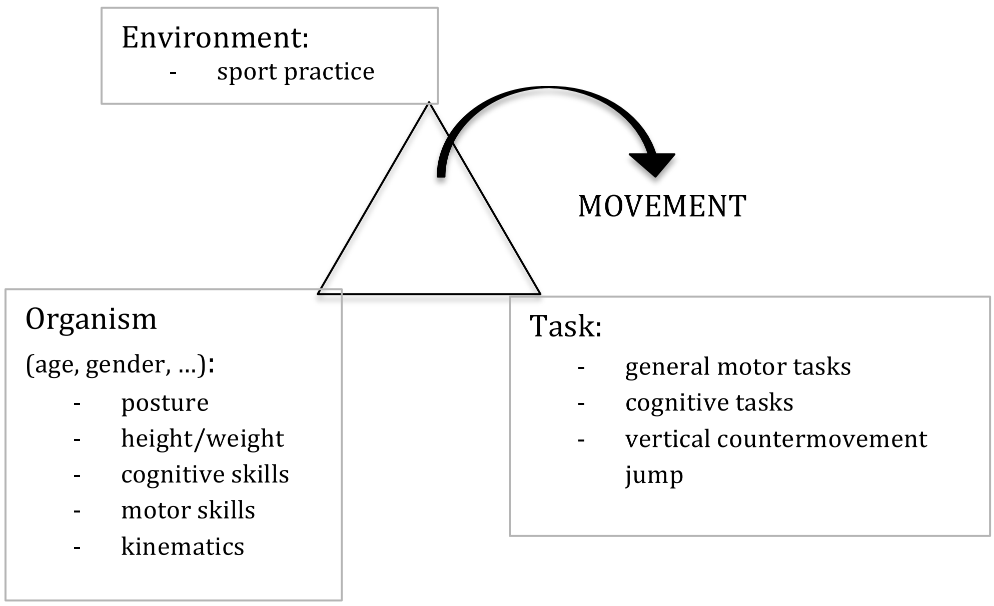


Figure 1. Edited Newell's Constraints Scheme[1] for young basketball players

The previously described outcomes support the importance of considering several constraints before assessing the motor abilities of the children. Taking into account the complexity of my research, I suggest promoting such as this multidisciplinary evaluation; in order to facilitate the specific needing of the children's motor development, this approach could be useful.

The last part of the study (Chapter 8) differentiates from the rest of the work because it refers to younger children aged between 3 and 6 years. This preschool age-band is peculiar because the children experiment new complex movements, and improve their abilities about the general movements[23]. They improve and increase their motor competences. In fact, this developmental age-band seems the most convenient for the motor learning imprinting.

Surprisingly in Italy, there is a lack of movement program to engage pre-schooler children in the motor activity. On the contrary, there are many specific sports proposals for this age-band. Even if the children should first develop the general motor prerequisites, often they early start trying a sport practice.

The purpose of this study is to verify the feasibility and the utility to propose the Australian Animal Fun protocol[24] to Italian pre-schooler children. The results support the feasibility of introducing Animal Fun for the Italian children as a pre-school general motor program. After one month of Animal Fun the changings I found out involved aiming and catching (quantitative improvement), balance (quantitative improvement), and manual dexterity (qualitative improvement) tasks.

Even if a control group doesn't exist, this consistent outcome suggests that pre-schooler children need this kind of motor activity.

I can affirm that in this age-band they don't need sport specific proposal, to specialize in throwing or shooting gestures: they would benefit from a general motor skills developmental program. Furthermore, these children don't afford physical education, nor at school, neither in the gym. Even if they are already practising a sport, they don't have other motor learning possibilities. Through this kind of activity, they can better improve their general movements performance, which are necessary prerequisites for the future sport practice. Moreover, in this study, I have not assessed the related benefit that this activity could bring. Anyway, taking into account the consistent literature, I suppose that this kind of activity could also have an influence on cognitive and socio-emotional attitudes[25 26].

Through these results, I can support and promote the introduction of Animal Fun –or similar programs- as a pre-school compulsory activity. During the school-time the children have to develop several different competencies. In order to prepare the children to the writing and reading processes, the manual dexterity is the only motor skill trained at the school. By the way, there are many other motor abilities that a child should learn and practice.

The pre-schooler programs should involve motor development too. The teachers should be also able to face this duty. In order to furnish an enjoying, flexible, imaginative program, the Animal Fun would be a useful instrument. The coaches, the educators, and the trainers of these young children should also take into account general and complete motor proposals, like Animal Fun.

This research has convinced me, that the clumsiness and the motor awkwardness must be assessed considering the environmental, individual and task aspects for each subject. By the way, in my opinion, the involvement of very young children in a controlled general motor program could be useful to prevent these motor alterations. The movement means health, and the children deserve to take care of it.

Through this research project I tried to give a contribution with normative descriptive data about the motor and cognitive development of the sporty children. This study would represent a cue for trainers and educators in the lack of evidence Italian context.

BIBLIOGRAPHY

[1] Newell, K. M. (1985). Coordination, control and skill. In Advances in Psychology (Vol. 27, pp. 295-317). North-Holland.

[2] Balagué, F., Troussier, B., & Salminen, J. J. (1999). Non-specific low back pain in children and adolescents: risk factors. *European spine journal*, *8*(6), 429-438.

[3] Leppänen, M., Pasanen, K., Kujala, U. M., & Parkkari, J. (2015). Overuse injuries in youth basketball and floorball. *Open access journal of sports medicine*, *6*, 173.

[4] James, W. P. T. (2009). WHO recognition of the global obesity epidemic. *International journal of obesity*, *32*(S7), S120.

[5] Taylor, E. D., Theim, K. R., Mirch, M. C., Ghorbani, S., Tanofsky-Kraff, M., Adler-Wailes, D. C., ... & Yanovski, J. A. (2006). Orthopedic complications of overweight in children and adolescents. *Pediatrics*, *117*(6), 2167-2174.

[6] Gushue, D. L., Houck, J., & Lerner, A. L. (2005). Effects of childhood obesity on three-dimensional knee joint biomechanics during walking. *Journal of Pediatric Orthopaedics*, *25*(6), 763-768.

[7] Calvete, S. A. (2004). Relationships between postural alterations and sports injuries in obese children and adolescents. *Motriz*, *10*, 67-72.

[8] Smith, A., O'sullivan, P., & Straker, L. (2008). Classification of sagittal thoraco-lumbo-pelvic alignment of the adolescent spine in standing and its relationship to low back pain. *Spine*, *33*(19), 2101-2107.

[9] Struzik, A., Pietraszewski, B., & Zawadzki, J. (2014). Biomechanical analysis of the jump shot in basketball. *Journal of human kinetics*, *42*(1), 73-79.

[10] Swartz, E. E., Decoster, L. C., Russell, P. J., & Croce, R. V. (2005). Effects of developmental stage and sex on lower extremity kinematics and vertical ground reaction forces during landing. *Journal of athletic training*, *40*(1), 9.

[11] Meylan, C. M., Cronin, J. B., Oliver, J. L., Hughes, M. G., & McMaster, D. (2012). The reliability of jump kinematics and kinetics in children of different maturity status. *The Journal of Strength & Conditioning Research*, *26*(4), 1015-1026.

[12] Cremonini M. (2002) Le favole nel minibasket. Retrieved: July 2nd, 2018. From http://www.basketservice.it/AREA%20TECNICA/MINIBASKET/MBD070.pdf.

[13] Mondoni M, Avanzino R. (2014). Manuale di pallacanestro. Tecnica e didattica. Vita e pensiero. ISBN:8834324994, 9788834324998.

[14] Cremonini M, Pellegrino FM. (2010). Minibasket. L'emozione, la scoperta, il gioco. Federazione Italiana Pallacanestro.

[15] Rosenbaum, D. A. (2009). *Human motor control*. Academic press.

[16] van der Fels, I. M., te Wierike, S. C., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of science and medicine in sport*, *18*(6), 697-703.

[17] Bisagno, E., & Morra, S. (2015). Analysis of the Relation between M-Capacity Development, Expertise and Motor Learning in Young Volleyball Players. In *EAPCogSci*.

[18] Luz, C., Rodrigues, L. P., & Cordovil, R. (2015). The relationship between motor coordination and executive functions in 4th grade children. *European Journal of Developmental Psychology*, *12*(2), 129-141.

[19] McGinnis, P. M. (2013). *Biomechanics of sport and exercise*. Human Kinetics.

[20] Rizzolatti, G., & Sinigaglia, C. (2006). *So quel che fai: il cervello che agisce ei neuroni specchio*. R. Cortina ed.

[21] Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review*, *30*(4), 331-351.

[22] Rigoli, D., Piek, J. P., Kane, R., & Oosterlaan, J. (2012). An examination of the relationship between motor coordination and executive functions in adolescents. *Developmental Medicine & Child Neurology*, *54*(11), 1025-1031.

[23] Zoia, S. (2004). *Lo sviluppo motorio del bambino*. Carocci.

[24] Piek, J. P., McLaren, S., Kane, R., Jensen, L., Dender, A., Roberts, C., ... & Straker, L. (2013). Does the Animal Fun program improve motor performance in children aged 4–6 years?. *Human movement science*, *32*(5), 1086-1096.

[25] Piek, J. P., Straker, L. M., Jensen, L., Dender, A., Barrett, N. C., McLaren, S., ... & Bradbury, G. (2010). Rationale, design and methods for a randomised and

controlled trial to evaluate" Animal Fun"-a program designed to enhance physical and mental health in young children. *BMC pediatrics*, *10*(1), 78.

[26] Cairney, J., Rigoli, D., & Piek, J. (2013). Developmental coordination disorder and internalizing problems in children: the environmental stress hypothesis elaborated. *Developmental Review*, *33*(3), 224-238.

Attachment 1
(Chapter 6)

DV	IV	Slope	Intercept	R2
MD	Denomination	0,26	8,70	0,06
MD	Inhibition	0,17	8,72	0,04
MD	Switching	0,09	9,95	0,01
MD	Corsi Front	0,02	4,46	0,00
MD	Corsi Back	0,08	3,49	0,04
AC	Denomination	0,24	8,35	0,03
AC	Inhibition	0,04	10,07	0,00
AC	Switching	0,08	9,81	0,00
AC	Corsi Front	-0,01	4,85	0,00
AC	Corsi Back	0,01	4,19	0,00
BAL	Denomination	0,23	8,71	0,02
BAL	Inhibition	0,09	9,44	0,00
BAL	Switching	0,06	10,15	0,00
BAL	Corsi Front	-0,05	5,20	0,01
BAL	Corsi Back	0,03	3,99	0,00
MABC-2	Denomination	0,38	6,76	0,08
MABC-2	Inhibition	0,19	8,23	0,03
MABC-2	Switching	0,19	8,57	0,02
MABC-2	Corsi Front	0,00	4,64	0,00
MABC-2	Corsi Back	0,09	3,28	0,03
MMSA	Denomination	0,40	7,03	0,11
MMSA	Inhibition	0,50	5,01	0,25
MMSA	Switching	0,35	7,03	0,10
MMSA	Corsi Front	0,10	3,57	0,06
MMSA	Corsi Back	0,11	3,08	0,06