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The Study of the Characteristics of Boccia Balls:

A Proposal for Regulation

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The Study of the Characteristics of Boccia Balls:

A Proposal for Regulation

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“O mundo está nas mãos daqueles que têm a coragem de sonhar e de correr o risco de viver seus sonhos.”

Paulo Coelho

Dedicatória

À Deus

que sempre me deu força e coragem durante esta caminhada.

Aos meus pais

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RESUMO

O presente estudo foi dedicado a investigar as características das bolas de Boccia e seu comportamento quando são submetidas a testes pré-definidos, e desta forma avaliar as suas propriedades mecânicas. A perceção tátil do atleta e do assistente em relação ao seu kit de Boccia, também foram abordados com o teste de rigidez/deformação. No primeiro estudo foram avaliadas 208 bolas de Boccia que foram submetidas a 6 testes diferentes, e mensurados o: peso, perímetro (ball template test), diâmetro, coeficiente de restituição no impacto com o solo (rebound Test) (realizado com 149 bolas), resistência de rolamento numa superfície inclinada (ramp Test) e a deformabilidade dimétrica (stiffness test). No segundo estudo foram avaliados 5 atletas das classes BC1, BC2, BC3 e seus respetivos assistentes, tendo o resultado do teste de rigidez sido usado para comparar com a perceção tátil dos atletas/assistentes. Calculou-se a estatística de média e desvio padrão de cada teste para analisar o desempenho das bolas no primeiro estudo, bem como no segundo a média e o teste de Spearman's Rho. Como resultados do primeiro estudo, obtivemos no peso das bolas a média de 275.58 g ± 4.97 g, o coeficiente de restituição com 0.169 ± 0.05 e a rigidez/deformação com 73,58 mm ± 6,52 mm. Foi observado também que tanto no teste da rampa como no teste de rigidez, as bolas azuis obtiveram uma maior reprovação. No segundo estudo, os assistentes obtiveram um total de 41% de acertos, enquanto os atletas acertaram 36%. Os atletas acertaram 40% da sequência das bolas vermelhas, enquanto os assistentes acertaram 46% da sequência das bolas azuis. Em relação aos resultados, o teste de rigidez satisfaz os requisitos de avaliação das bolas de Boccia, considerando as suas propriedades mecânicas, tornando-se um teste de fácil e confiável. Este teste também auxilia durante o jogo na sequência das bolas, da mais macia até a mais rija.

Palavras-Chave: BOCCIA, REGULAMENTAÇÃO, TESTE DE RIGIDEZ, PERCEPÇÃO TÁTIL

ABSTRACT

The present study was devoted to investigate the characteristics of Boccia balls and its behavior when they are subjected to predefined tests, and through this way evaluates their mechanical properties. The tactile perception of the athlete and the assistant in relation to its Boccia kit were also addressed with the stiffness/deformation test. In the first study 208 Boccia balls were evaluated and submitted to six different tests and weighted. For all the ball the perimeter (ball template test), diameter, the coefficient of restitution on impact with the ground (rebound Test) (tested with 149 balls), the rolling resistance on an inclined surface (ramp test) and a diametrical deformability (stiffness test) was measured and recorded. In the second study 5 athletes of BC1, BC2, BC3 and their assistants were also evaluated. The result of the stiffness test was used to compare with the tactile perception of athletes / assistants. Mean and standard deviation of each test were determined in order to analyse the balls performance in the first study, as well as in the second the mean and Sperman's Rho Test. For the first study, it was obtained for the balls an average weight of 275.58 g ± 4.97 g, a restitution coefficient of 0.169 ± 0.05 and for the stiffness/deformation 73.58 mm ± 6.52 mm. It was also observed that in both, the ramp test and the stiffness test, the blue balls had a higher failure rate. In the second study the assistants obtained a total of 41% hit, while the athletes did 36%. Athletes hit 40% of the sequence of red balls, while the assistants agreed 46% of the sequence of blue balls. Regarding the results, the stiffness test satisfies the requirements of evaluating the Boccia balls, considering its mechanical properties, making it an easy and reliable test. This test also helps during the practice of the game in the sequencing of the balls, from the softer to the firmer.

Keywords: BOCCIA, REGULATIONS, STIFFNESS TEST, TACTILE PERCEPTION.

LIST OF ABBREVIATIONS AND SYMBOLS

ANDE - National Association of Sports for the Disabled

AT - Athlete

AS - Assistant

BC 1 - Boccia Classification 1

BC 2 - Boccia Classification 2

BC 3 - Boccia Classification 3

BC 4 - Boccia Classification 4

BISFed - Boccia Internacional Sports Federation

CAD - Computer Aided Design

CNS - Central Nervous System

COR - Coefficient of Restitution

CP - Cerebral Palsy

CPISRA - Cerebral Palsy International Sports and Recreation Association

CPS – Cerebral Palsy Severe

EXP – Experimental

FADEUP - Faculty of Sports of University of Porto

FIFA - Fédération Internationale de Football Association

FPDD - Portuguese Sports Federation for Persons with Disabilities - Boccia

INEGI - Laboratory of Optics and Mechanical Experimental

LABIOMEP – Biomechanics Laboratory of the University of Porto

LOME - Laboratory of Optics and Experimental Mechanical

mm – millimetres

PCAND – Cerebral Palsy - National Association for Sport

α – significance coeficient

A – Amplitude

ε – Deformation

σ – Standard deviation

$\bar{x}$ – Mean

CHAPTER I

INTRODUCTION

1.1 Introduction

Since the Boccia balls are a decisive equipment of the game, their mechanical properties, geometric characteristics and its exterior texture are very important in sport results. Thus, the teams try to adjust these properties for the game according to the player's needs. It is necessary to control the manipulation of the balls in order to ensure justice and equality among all contestants.

Given this possibility of manipulation of the balls, currently there are employed very heterogeneous balls, specifically softer balls which present a higher mechanical deformation. Although the level of deformability of these balls is acceptable for the athletes, this way they may have different options depending on the game strategy. In the case of excessively soft balls, there is a distortion of the essence of the game by preventing them from rolling on the ground, jeopardizing the competition. In other words, the large deformability of the balls allows lowering its center of gravity, causing an increase of the contact area with the floor and absorbing much more of the energy of impact than other balls. In this case the athlete after placing one of these balls properly knows that the opponent will hardly be able to undo the move.

In this study we discuss the characteristics of Boccia balls and their behaviour when they are subjected to specific tests, and thus evaluate their mechanical properties. The tactile perception of the athlete as well as of the assistant in relation to the Boccia kit was also addressed through the stiffness/deformation test.

This evaluation seeks to answer a question regarding the problem felt in recent years due to a constant change in the characteristics of Boccia balls. Several teams have changed the initial structure of the Boccia ball to obtain advantages for their athletes. These changes have influenced the game, stripping out the beauty of it, but above all creating competitive imbalances that do not necessarily promote the best performance of the athletes.

The research here presented was elaborated by the request of the BISFed's (Boccia International Sports Federation) President of the Committee of

Development Helena Bastos through the Biomechanics Laboratory of the University of Porto, (LABIOMEP), aiming to develop a method for the evaluation of the mechanics properties of the Boccia's balls.

This study also produced a report that was sent to the members of BISFed from different countries and can be found in the attachment 1. It was intended to spread the results of this work and obtain feedback from the different federations regarding the suggested test to be part of the balls' control that occurs in the beginning of competitions.

1.2 Structure of the Dissertation:

This dissertation is organized according to the "Scandinavian Model" and divided into six chapters, which are organized as follows:

Chapter I - refer to a general introduction, which contains a presentation and justification of the theme and the purpose of the study.

Chapter II - will present a literature review about the main subjects to better clarify the goal of this study. The history of the sport, participants, characteristics, and importance of the balls for the game are presented.

Chapter III and IV - are devoted to describe the studies carried out which will be presented in a scientific paper, and the text are in accordance with the rules of the journal in which the article is published. The study presents a brief introduction, describes the methodology used, presents the obtained results, and ends with a discussion of the results and the main conclusions of the study as well as the corresponding bibliography.

Chapter V - point out the findings, conclusions and suggestions for future studies.

Chapter VI contains the attachments relating to this dissertation. Attachment 1 is composed of a report sent to countries belonging to BISFed. Attachment 2 is the figure of the Boccia court. Finally in the attachment 3 is shown the scale used to assess athletes and assistants.

CHAPTER II

LITERATURE REVIEW

2.1 A Historical Background of the Boccia

Boccia is a Paralympic sport directed to a specific group of people presenting certain types of disabilities, such as: cerebral palsy, spinal cord injury, muscular dystrophy, among others. The game presents six blue balls, six red balls and one white ball, and the goal of the game consists in the athlete to position their red or blue balls as close as possible to the white ball, the target. This game can be played as both recreation activity and professional performance.

The word 'Boccia' is derived from the Italian word meaning to bowl, and this family of sports is probably the earliest game ever played by mankind – carvings of Egyptian figures throwing stones have been recorded as early as 5200 BC (BISFed, 2014). Despite the Boccia being a recent sport, its existence as a form of competition is from about 30 years, even though it originates in the antiquity. According to Campeão (2002), the sport was adapted from bowling in grass, which was a game of Italian origin for closed court.

According to the Cerebral Palsy - National Association for Sport (PCAND) (2014), the Boccia is a sport of universal character originated from an ancient Greek game progressing during the Roman Empire originating some games in which we highlight the *bowling* and the *Pentaque*. The National Association of Sports for the Disabled (ANDE) (2013), states that in Greece there was an activity which consisted in launching large stones to existing targeted described as smaller stones. Campeão (2002) states that, there were references to practice in Classical Greece in the sixteenth century B.C., as well as more recently through a French game described as *Petanque* whose modern rules were established in a town near Marseille in 1910,.

According to Marta (1998), the Boccia arises in the twentieth century in the Nordic countries, with a strong representation in Denmark, in the format of a sport for all, including the elderly and handicapped persons with merits. According to ANDE (2013), the Boccia is conceived as a Paralympic Sport in 1984, aimed as a sport for people who have a high degree of motor impairment and /or multiple. The Boccia is one of the few sports in the Paralympic Games which is not included in the Olympic Games program. As described by Valente (2005) Boccia is a Paralympic sport in which persons of different sexes can compete together.

The Cerebral Palsy International Sports and Recreation Association (CPISRA), was created in 1978, having the responsibility to enroll people with cerebral palsy or related neurological conditions into activities of sport and recreation. Initially CPISRA was responsible for managing the Boccia. However, due to the expansion of this sport, they felt the need to create an international federation directed only to the Boccia (CPISRA, 2014). Consequently, the Boccia International Sports Federation (BISFed) was created in 2013, bringing the responsibility to work exclusively with the Boccia worldwide, with the goal to support and develop the sport in order to be accessible to everyone, as well as to help the athlete in its Paralympics development (BISFed, 2014).

In Portugal, the Boccia, together with other sports conditioned to disable people, is managed by Cerebral Palsy - National Association for Sport (PCAND). Since 2010 it is committed to promote accessibility, likewise, to guide the sport inside the communities where the athlete lives, adding existing structures to regular sport (PCAND, 2014). In Santos (2008) statements, the Portuguese Association of Cerebral Palsy, through the CPISRA, held the first event in Portugal in the Algarve, 1982, in which Boccia was mentioned.

National competitions are held around the country, this way the strongest athletes are selected for international competitions. According to Santos (2008) Boccia is becoming increasingly known due to international victories of the Portuguese athletes. According to the ranking BISFed 2013 in table 1, we can see the first three rankings of the best positioned countries in each class: individual, pairs and teams. We highlighted Korea, Great Britain, Portugal and Thailand, which appear significantly in different classes.

Table 1 –Ranking of countries in Boccia in 2013

Position	BC1 Individual	BC2 Individual	BC3 Individual	BC4 Individual	Team	BC3 Pair	BC4 Pair
1º	Great Britain	Brazil	Korea	China	Thailand	Greece	Brazil
2º	Thailand	Portugal	Portugal	Canada	Great Britain	Portugal	Czech Republic
3º	Thailand	Korea	Korea	Hong Kong	Korea	Belgium	Great Britain

In Portugal this sport also has great impact in the older population, becoming known as *Boccia Senior,* targeting an audience of men and women over 60 years old. Serra (2006) affirms that the competition of Boccia, for these people, has grown rapidly, achieving the goal to stimulate the sport inside the older population, who were sedentary.

2.2 The Benefits of the Boccia Sport

Boccia can be played recreationally, providing larger integration among practitioners, increased sociability, and secondly competitively, obtaining the benefits cited for recreation, as well as sporting success through hard training.

According to Campeão (2003), Boccia is a constantly growing sport in the world and quite challenging, especially for providing inclusion and equality of persons with a severe degree of motor dysfunction with others who do not have disabilities. According to Jerônimo et al. (2009), people with Cerebral Palsy Severe (CPS) have the sport as a tool of paramount importance for their inclusion in society; it intervenes in the discovery of their potential; overcoming the limits and valuing themselves. "*Boccia is a fun sport for children with Cerebral Palsy (CP). This sport requires coordination of the extremities, thought, teamwork, and emotional control, and therefore provides both leisure and competition functions. Many of the children with CP like to participate in this game, interact with people, and make new friends, thereby enhancing their quality of life"* (Huang et al., 2014, pp. 394). According to Lourenço (2013), it is through sport that many individuals with disabilities feel integrated with success, gain motivation for other activities, believing they have the skills and can successfully develop. According to this author, the Boccia works together on improving the balance, laterality, as well as, increasing the articular range of motion.

The Boccia begins from recreation activities till the training of knowledgeable athletes, being a great opportunity for people with CPS to join a sport (Marta 1998). According to Serra (2006), the strategy and tactics are key factors in the game. Any interference or uncontrolled path of a ball thrown into the game area could jeopardize its final position relative to the target ball. Branco (2002) states that Boccia is a game in which the athletes will have to develop their cognitive abilities, skills and precision of precise movements, such as the accuracy of the launch, and the main one is the strategic capacity to solve with maximum success the problems presented by their opponents.

This is a sport of great precision requiring high levels of attention, concentration, perceptual-motor skills, cognitive ability, emotional control, highlighting the visual-motor coordination of the athlete (Valente, 2003).

2.3 General Description of the Game

The rules of the game are established by BISFed. The game consists of 6 blue balls, 6 red (one color for each team) and one white, in which a draw is conducted to define which colour ball each athlete will play. The main goal of the game is to position the blue and red balls closer to the white one. The referee decides which athlete will play, after measuring the distance of the colored ball closest to the target ball, the white ball. After checking the length, the referee shows the color of the next ball in a racket that has both red and blue colors, this way the athlete who has the color of the ball indicated on the racket knows he is the next to throw the ball. Figure 1 illustrates specific equipment required to play Boccia.

Figure 1 – Specific equipment required to play Boccia

The Boccia can be played on any flat surface such as: polished cement, wood floors, natural or synthetic rubber. The Boccia court has 12,5 meters long by 6 meters wide. (BISFed 2013). The playing area is divided in two parts: six boxes, where the athletes are positioned during the game, and the play area where the white ball is considered valid (Appendix 2).

Each athlete has his/her own sport equipment, which may create a large variety, and for that reason a rigorous assessment of all equipment used in games is necessary. However, the Boccia ball presents a simple criterion of evaluation, which allows a wide range of differences between them. According to BISFed (2013), the balls should weight 275 grams +/- 12 g, and have a perimeter of 270 mm +/- 8mm, not requiring a logo.

In case the balls brought by the athletes do not meet the rules for any reason, the balls of the organization can be used. This change can be seen as a simple punishment, as the athlete does not know the ball's skin, texture, rigidity, and behaviour on the floor of the competition. However this change can become a severe punishment if the athlete does not know the entirety of the game's materials, in this particular case the ball will hinder their performance both in planning and execution of the move.

2.4. Sports Classification

The Boccia is a sport for many types of disabilities which affect the motor system, but these shortcomings have to be within the standard functionality of each class. To classify each athlete there is a functional classification, which according to the Manual of Functional Classification ANDE (2012), provides a condition of equality in competition. The athlete achieves the merit of victory by technical and tactical, and not because of their motor, sensory and intellectual part caused by their disability.

According to Valente (2005), athletes have very different characteristics in the technical patterns, thus the existence of a functional classification to standardize the capabilities.

"*BISFed provides an opportunity for individuals with severe neurological impairment affecting the central nervous system (CNS), including spastic hypertonia, dystonia, athetosis and ataxia in all four limbs and individuals with severe locomotor dysfunction in all four limbs of NON-Cerebral origin such as muscular skeletal disorders and limb deformities to compete in sport. All athletes must provide medical evidence of their underlying condition and clinical diagnosis"* (BISFed – Boccia Classification Rules, 2013, pp, 04).

In the game of Boccia the athletes are framed in Boccia Classification (BC) starting from its Functional Classification, there are four classes: BC1, BC2, BC3, BC4. According to the Boccia Classification Rules of BISFed (2013, pp 25-33), a summary of guidelines for each class is present below:

4.2.1 BC 1 Classification: Athletes who are diagnosed with Spastic Quadriplegia or Athetosis or who may have a mixed picture including those with severe Ataxia.

- Severe impairment affecting all four limbs;
- Spasticity ASAS Grade 3-4 (ABOVE Grade 3) with or without athetosis;
- Limited functional range of movement and/or limited functional strength in all extremities and trunk;
- Or an athlete with severe athetosis or dystonia with limited functional strength and control;
- Or severe ataxia limiting coordination, grasp and release;
- Dependent on a powered wheelchair or assistance for everyday mobility and is unlikely to use a manual wheelchair for any length of time;
- Athletes with athetosis may play from a manual wheelchair, often propelled using their lower limbs;
- Athletes with athetosis may walk;
- Athletes, who fit the above physical profile but demonstrate that they are unable to consistently throw the ball into the play field using their hands and have no sustained grasp and/or functional release, can be considered as a BC1 foot player.

4.2.2 BC 2 Classification: athletes who are diagnosed with spastic Quadriplegia or with athetosis/ataxia.

- Impairment affecting all four limbs;
- Spasticity ASAS Grade 2-3 with or without athetosis;
- Or an athlete with athetosis;
- Moderate impairment of function and may have some limitation in active functional range of movement due to weakness or spasticity or lack of control affecting the upper limbs/trunk;
- Athletes may use a manual or powered chair for everyday mobility;
- Athletes may walk short to moderate distances;

4.3.3 BC 3 Classification:

- Athletes who fit the physical profile of a BC1 (CP) or BC4 (Non-CP) athlete (as detailed in each classification) but who are unable to hold/throw the ball may be eligible as a BC3 athlete provided they fulfil the below criteria.
- Athletes must demonstrate that they are unable to hold the ball and have no sustained grasp and/or functional release or unable to propel the ball with their feet into the play field.
- Functionally athletes are unable to consistently propel a Boccia ball with purposeful direction and velocity into the play field (passing the +).
- BC 3 athletes will use an assistive device (ramp) to propel the ball onto the play field with the help of an assistant.
- Athletes may use a variety of methods to release the ball on the ramp, which may include but are not limited to a head pointer, mouth device or their hand/finger to hold the ball in position on the ramp and release the ball without any other external assistance.

4.2.4 BC 4 Classification: Athletes who are diagnosed with conditions of non cerebral origin who do not have spasticity, ataxia or athetosis.

- Athletes will have severe locomotor dysfunction affecting all four limbs;
- Moderate impairment of function and may have some limitation in active functional range of movement due to weakness and lack of control affecting the upper limbs/trunk/lower limbs;
- Overall muscle strength of 3/5 or less;
- Athletes may use a manual or power chair for everyday mobility;
- Athletes may walk with assistance or using a walking aid;
- Sport functional profile and mechanics of throwing is similar to Boccia Class 1 or 2 athletes.
- Athletes who fit the physical profile of a BC4 athlete as detailed above however they are unable to hold the ball and have no sustained grasp and/or functional release and are unable to consistently throw a Boccia ball but have enough lower limb function to consistently propel the ball with

their foot into the play field with purposeful direction and sufficient velocity will be able to play as a BC 4 Foot player.

2.4.1 Characteristics of gripping

Athletes with the same type of disability may have different functional characteristics. Based on these differences, was observed that the same functional class athletes have different ways on how to catch the ball and make the launch. The rough kind of balls, facilitate performance in athletes who have difficulty to hold. A smoother ball for example reduces the adhesion of the athlete's hand so it can hold the ball.

According to Boccia Classification Rules (2013, pp.25-33), the characteristics of the classes with respect to functional and hand grip are as follows:

4.2.1 BC 1 Classification:

- Clinically there will be weakness of the hand and fingers, which may be due to tone, spasticity and deformities at the wrist, and fingers and therefore, athletes will grasp the ball in a variety of ways.
- There will be a loss of fine motor control and coordination within the hand.
- Athletes may demonstrate delayed release of the ball as a result of flexor tone/spasticity or weakness in the extensors.

4.2.2 BC 2 Classification:

- Clinically there will be some involvement of the hand and fingers, which may be due to tone, spasticity and occasionally deformities of the wrist and fingers but they may be able to use all of the hand to have a more controlled grasp of the ball.
- There will be some impact on fine motor control and coordination within the hand and fingers but manual dexterity will be better than in the BC1 classification.

- Athletes will have sufficient manual dexterity to manipulate the ball in their hand and to throw.
- Athletes may demonstrate delayed release of the ball as a result of mixed tone or weakness in the wrist and finger extensors.

4.2.3 BC 3 Classification:

- Athletes must demonstrate that they are unable to hold the ball and have no sustained grasp and/or functional release or are unable to propel the ball with their feet into the field play.
- Functionally athletes are unable to consistently propel a Boccia ball with purposeful direction & velocity into the play field (passing the +).

4.2.4 BC 4 Classification:

- Athletes may be able to demonstrate full ROM (Rang Of Motion) of the wrist, thumb and fingers, however there will be weakness Grade 3/5 muscle strength or less on clinical assessment.
- Intrinsic hand and grip strength weakness will be evident on power grip and pinch grip testing. This will be demonstrated functionally by weakness of functional grasp (flexors) and on release of the ball (extensors).
- There may be some loss of fine motor control and coordination within the hand as a result of muscle weakness and also manual dexterity will be affected in some way.

2.5 Influence of the balls for the game

2.5.1 Types of skins, fillers and colouring of the balls:

The Boccia balls are available in many parts of the world. In general the skin that surrounds the ball is synthetic, it may be rougher or softer, and can also find in natural leather or fabric (velvet). The balls buds are stitched together leaving a little skin inside. When the ball is hard, the stitching becomes more apparent, noting that in some points the ball is pointed.

Generally, the balls have a form of 12 pentagon buds (figure 2), which is obtained after sewn the shape of the ball. In some brands were found balls with less seams, that is, instead of having 12 pentagons as usual, one of the seams is not made, thus joining two pentagons, giving a total of only 6 buds (figure 3). In this case, the ball is looking like a tennis ball. There is still no scientific evidence to support greater effectiveness of the balls having only 6 buds in relation to the deviation that can occur when they contact with the ground.

Figure 2: Boccia balls with 12 buds

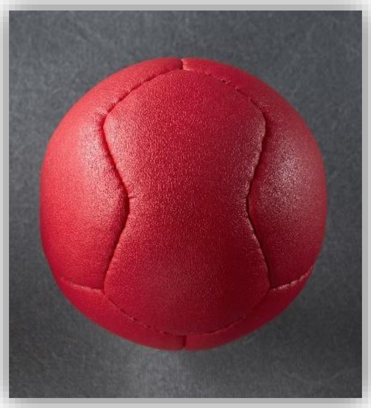

Figure 3: Boccia balls with 6 buds

The material found inside the ball when new or without undergoing manipulation by the trainer / athlete, are generally small plastic granules, as well as rubber granules of different diameters. With the difference of material found, the balls may suffer different behaviours in court, because they have different properties.

In the contacts with some Boccia balls manufacturers, it was referred that the process of colouring the balls is the same for all three colours. However we realize that the blue ball becomes softer faster than the other colours. It was referred to us that when the ink comes into contact with the leather it undergoes a chemical reaction and the use of the ball follows the above-mentioned fact.

2.6 The evolution of the sport rules regarding the evolution of the material

Recently more attention has been given to the behaviour of the balls on the field. It was observed that there is something different from the way that the athlete holds the ball. They simply take the ball with the hand which is in the format of tweezers. This occurs because the balls are increasingly softer. As there is nothing in the official rules to address this issue, except the weight and the perimeter previously mentioned, everything else fits well in this saying: "what is not forbidden is allowed." In the case of extremely softer balls, the contact with the ground is as if it slides and not rolls. According to Weizman et al. (2013) specific ball behaviour is usually expected by players, and any unexpected behaviour disturbs the flow of a ball game. Some conditions that influence an athlete's performance are: (i) the behaviour of the balls and the changes occurring in them with the increasing number of hours of use, (ii) the gutters (accessory used for the BC3 class) and (iii) the floors where it is played (Serra, 2006).

After released, the extremely soft balls remain static and the opponent cannot move it with their own balls. In a practical example of the game, it is as if the athlete after releasing their white ball, can position their first coloured ball together with the white one. As this type of ball is too soft it becomes almost impossible for the opponent athlete to move it. Thus the athlete is at a disadvantage not by having used the wrong strategy or not having experience in the game, but due to the material used by another athlete. This was also observed in BC3 class in which the athlete uses a ramp to play, and which the ball's behaviour on the field is similar to the previous case.

When the ball is softer, the position of the centre of gravity is modified, instead of staying in the centre of the ball will now be lower, which makes the ball becomes more stable, making it difficult to move. Thus increasing their contact area gets harder to drag in the floor. According to Ferraro & Smith (cited above by Assis and Ravanelli, 2008) if the centre of gravity is lowered from the surface and if the support base is larger, higher will be the stability of the body.

With the evolution of the sport, the material also evolves to keep up with its development. Both the Olympic and Paralympic sports, in those sports in which its allowed to bring own equipment for the competition, specific equipment for each athlete are developed, thereby allowing the athlete to get better performance. One can cite, for example, the pole vault, where each player has its own specific material, in which the pole can be built according to the specific characteristics of the athlete.

Regarding the first issue, do the balls can undergo many changes over its lifetime? What we can observe in daily training with athletes is that after a certain time of use the balls begin to lose their properties. We do not know certainly the exact period when this process begins and in which brands it occurs as we have no scientific data to affirm.

The skin will suffer the natural wear, as well as the seam will loosen, which facilitates the handling of the material therein. But even without this loosening of stitching the balls can be easily manipulated, because it can be opened and sewed again.

According to Serra (2006), changes in the skin of Boccia balls may vary by brand and with the time of use. In the alterations related to the seam, it may become more homogeneous, a difference existent from one brand to another.

The brands of the Boccia balls, besides being different in the type of skin, also differ in the interior of the ball filling as was mentioned above. Initially, when they leave the factory, it is known what kind of material is inside of each ball. However, as there is no rule regarding the material placed inside the ball, this has become increasingly a source of concern. There is a growing manipulation of the contents of the balls by both athletes and coaches to make them more soft or hard.
Despite the concern presented above, persists unfamiliarity about the content of the balls although they preserve both their weight and perimeter, problematic topic for lack of research related to this matter. The truth is that the balls do not appear to have been tampered because apparently the sewing looks normal. What we have seen is that there are increasingly numbers of extremely soft balls.

Boccia is a sport that has shown a constant evolution with the introduction of new equipment such as gutters that have been of wood and now they are mostly in acrylic, materials inside and coating of the ball, for example. But this evolution should be governed by rules and regulations, standardization of construction of the balls, and any materials that may be used to fill the inside of the balls as well as the skin type. Although the rules are already set regarding the size and weight of the balls, the type of material put inside them is what determines their behaviour. Likewise depending on the coating used on its skin they can slide more or less.

For all the foregoing, we are of the opinion that there is a need to better define what can be used as material in construction of Boccia balls, so there must be a standardization in order that no athlete is disadvantaged relative to another due to a difference in the type of balls used. It should prevail as the central aspect that the result should depend on the athlete's performance and not so much on to the large difference observed in the type of material used.

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CHAPTER III

EMPIRICAL STUDY I

PROPOSAL FOR REGULATIONS OF THE BOCCIA BALLS

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Abstract

In current days it can be observed an evolution on the equipment used in order for the athletes achieve better results in the competition, and Boccia is not an exception. However, to reach excellence in this sport some athletes and assistants are manipulating the Boccia balls, namely its rigidity/deformability, so misrepresent the essence of the game taking advantage to the fact that there are no regulation on the balls content. The purpose of this study is to evaluate the Boccia balls with simple but rigorous methods in order to regulate the characteristics of the balls used contributing to a more competitive game as well as enjoyable to see. To accomplish the purpose of this study a total of six tests were developed and measurements were performed in: weight, circumference (ball template test), diameter, coefficient of restitution on impact with the ground (rebound Test), rolling resistance on an incline surface (ramp test) and the deformability diametrical (stiffness test). As a result, the weight of the balls found was 275.58 g ± 4.97 g, the coefficient of restitution was 0.169 ± 0.05, and the stiffness was 73.58 mm ± 6.52 mm. It was also observed that in both the ramp test and the stiffness test, the blue balls had a higher disapproval rate. Faced to some weakness observed a new stiffness test was developed. We believe that this new stiffness test can meet the needs to assess the Boccia balls, taking into account their mechanic properties, making it easy to test and to apply and therefore more reliable.

Keys-words: Boccia Balls, Regulations, Stiffness test

3.1 Introduction

Boccia is a Paralympic sport directed to a specific group of people presenting certain types of disabilities, such as: cerebral palsy, spinal cord injury, muscular dystrophy, among others. Recently the game of Boccia has called attention not by the performance of athletes, but due to the materials used in the game, more specifically the balls. Depending on the type of ball launched, there are different forms of contact. According to Dickson et al. (2010) the three types of contact ball/floor which can be observed:

- *With a throw, the ball deforms on impact and the transition into the roll phase depends on the bounce behavior, i.e. the coefficient of restitution (COR) of the ball.*
- *Using the ramp, the floor contact depends on whether the ramp rests on the floor, enabling a smooth transition from ramp to floor, or whether the ramp is lifted off the floor in order to slow the ball down. In the latter case, the ball is airborne for a short period and finally impacts on the floor. (Figure 1)*
- *Lastly, during kicking, the ball will be compressed and initially skid over the surface before the conservation of momentum will start the ball to roll. (Figure 2)*

Figure 1: Athlete Class BC3

Figure 2: Athlete Class BC1 that launches with the foot

Accordingly to our vision of the game, contrarily to the statement presented in the first topic mentioned above, there would be a subdivision of the throwing, in throwing over the top (figure 3), and the low throw (figure 4). In the second the ball has a lower influence of the COR, analyzing the initial height of the launch and the impact with the ground that is smaller than when launched over the top.

Figure 3: Athlete of class BC1 throwing over the top

Figure 4: Athlete of class BC2 performing a low throw

Being the Boccia balls a decisive play equipment, their mechanical properties, geometric characteristics and exterior texture are very important in sports results. It is well known that with hours of daily training, the balls of Boccia will lose their properties, both in the leather constituting the ball covering as in the granules of plastic that exist inside; depending on the type of leather used, it expands and the seams of the balls start to open, allowing the material that exists in its interior to fall, thus decreasing its “natural” weight. This is more visible in classes BC1, BC2 and BC4 in which the ball has higher speed when touching the floor after being released, than in class BC3 where it scrolls in the rail which is closer to the ground.

But another important observation we have to take care is about the changes of the material that are introduced into the balls by some athletes and coaches. Cases confirmed in our research showed that the softer ball in our sample is the heaviest of them all. What gives us the certainty that it was manipulated, ie, the teams seek to adjust these properties according to the gaming needs of their athletes. We suspect that some material was added to the one originally placed inside the ball, but we are unsure because we didn’t use any type of invasive testing was used. Therefore, it is necessary to control the handling of the balls in order to ensure fairness and equality of all competitors.

Given this possibility of manipulation of the balls, very heterogeneous balls have been used, specifically as regards to the softer balls, which have a larger mechanical deformation. Although the level of deformability of the balls is acceptable, athletes may have different options depending on the game strategy. In the case of excessively soft balls, there is a distortion of the essence of the game, preventing the balls from rolling on the ground, jeopardizing the competition, that is, the great deformation of the balls allows lowering its centre of gravity, causing the increase of the contact area with the floor and absorbing the impact energy of the other balls. In this case, the athlete after placing one of these balls conveniently knows that the opponent hardly will be able to undo the move. According to Weizman et al. (2013) athletes know how the ball will behave, and when this behaviour is changed hinders the development of the game.

Another situation in which the distortion of the essence of the game may occur is when the athlete is able to place his color soft ball close to the white. This makes more difficult to the opponent to score or try to take out this ball in the next move and will condition on the game strategy of each athlete. That would be legal in the game, however these balls have very low stiffness and so the opponent cannot move them, even trying it hard.

This is due because the kinetic energy of an approaching ball is entirely absorbed by a softer ball (and converted via inner friction to thermal energy), whereas it is transferred entirely to a harder ball in terms of kinetic energy. (Dickson et al., 2010)

In Figures 5 and 6 two soft balls with the characteristics mentioned above are presented.

Figure 5 and 6: The Boccia very soft balls

It should be noted that according to the current rules of BISFed (2013) only the weight 275 gr. + / - 12 g, and the circumference 270 mm + / - 8mm are controlled. As demonstrated in the previous figures the balls would be accepted for competition, which made us think of new possibilities for other measurement of the balls to restore equality in the game.

The *Fédération Internationale de Football Association* (FIFA, 2014), has a quality standard for the balls. A set of tests was prepared to ensure that the ball have always the same mechanical properties. Tests such as the weight, circumference, sphericity, loss of pressure, water absorption, rebound, shape and size retention as well as balancing are part of this control. This quality control is needed in any sport to avoid problems such as the already exemplified above.

The purpose of this study is to evaluate the balls of Boccia with simple but rigorous methods, in order to regulate the characteristics of the balls used contributing to a more competitive game as well as more enjoyable to see.

3.2 Materials and Methods

3.2.1 *Sample*

The tests were developed and carried out in the Faculty of Sports of University of Porto (FADEUP) in partnership with the Laboratory of Optics and Experimental Mechanical (LOME) from Institute of Mechanical Engineering and Industrial Management (INEGI). The sample used in this study was composed by 208 balls of Boccia (17 white balls, 95 red balls and 96 blue balls), of different brands available on the market, with 39 new balls and the remaining balls used. Balls and athletes selected from national and international teams were involved in the testes. All the balls were marked with labels with a unique code for each one that indicates to which kit it belonged and with a random numbering.

3.2.2 *Methods*

Initially all the balls were weighed on a scale of type KERN - PLS with accuracy of 0.01g (Figure 7). Then, all the balls have been tested through the Ball Template used to confirm the circumference, (Figure 8). In accordance with the exact measurement we gauged the diameter of the ball in millimeters using a caliper from Sanny (Figure 9) and then we find the value of the circumference using the formula $C=\pi d$; in which the "C" corresponds to the circumference, for π we consider the approximate value of 3.14, and the "d" stands for the diameter.

Figure 7:Weight on a Balance

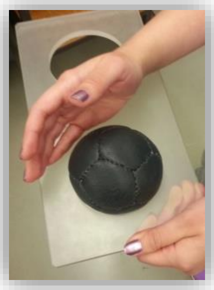

Figure 8: Ball Template

Figure 9: Measurement of the diameter

The rebound test (figure 10) consists in measuring the coefficient of restitution on the impact with the ground after the ball is dropped from a height of 2 meters, this test was adapted from the testing quality control of FIFA. After dropping the ball the first and second impacts are detected by a microphone that is placed closer to the ground. The impact height is given in centimetres and was obtained from data collected with a program that was developed in *Lome in Labview* software (figure 11). The result of the impact is given by a graph in which we could differentiate the first of the second impact by peaks in the recorded sound and thus obtain the flight time - T_f.

From simple physics of projectile motion, one obtains for the height of rebound (hr) by:

$$hr = \frac{1}{8} g {T_f}^2$$

where *g* is the gravitational acceleration. The Coefficient of Restitution (COR), was obtained by (1).

$$COR = \sqrt{\frac{hr}{hd}} \qquad (1)$$

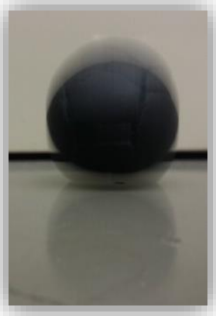

Figure 10: Rebound Test

Where hr is the height of the rebound in cm, divided by the initial height in cm hd. Figure 10 shows a result recorded from one impact.

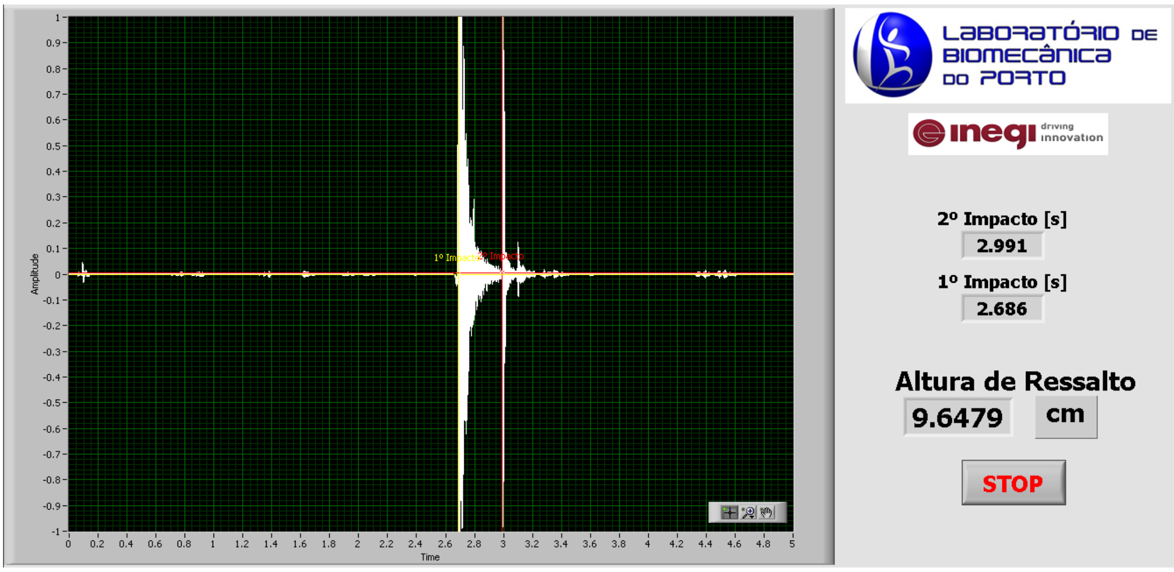

Figure 11 – Data recorded with the microphone from one impact of the ball with the floor

Another test performed was the ramp test. This one was suggested by the coach Roberto Filipe, and carried out by our team. In this test was measured the rolling resistance of the ball in the ramp. The ramp was made with acrylic and has a 12 degree tilt. This slope was defined by using the softest balls starting from a higher to a lower slope until they reach a slope in which it did not roll. In our tests the slope obtained was 12 degrees. The ramp used has a length of 52 cm and a width of 17 cm. At the beginning of the test the ball should be rounded up by the hand of the referee and placed at the beginning of the rail. To be considered valid the ball might roll through the entire rail and exit at the end of the path. This procedure was repeated 5 times changing the position of the ball defining that it would have to roll in 3 of 5 attempts. Figure 12 shows an image of the ramp test.

Figure 12 – Ramp test of a white ball

Then the test of deformability was performed. This test consists in checking the diametrical deformability of the ball. To test the ball deformation the device consists in a rig with a millimetre rule spanning from 0 to 100mm and a mass weighting 22,5 N. This weight was defined in such a way that it does not affect the properties of the ball.

Initially the ball diameter was measured in its natural position in the prototype. Then the weight was positioned slowly on the ball and its deformation can be directly evaluated using the graduated rule.

To exemplify the test two colors bands can be observed on the sidebar, red and green. For the ball to be considered valid the arrow must be in the green one which means that the ball is within the limits. The minimum stiffness required is located at 68mm (diameter). If the arrow indicates that the ball is in the red area it means that it has a high deformation and it must be considered invalid/disapproved, see figure 13.

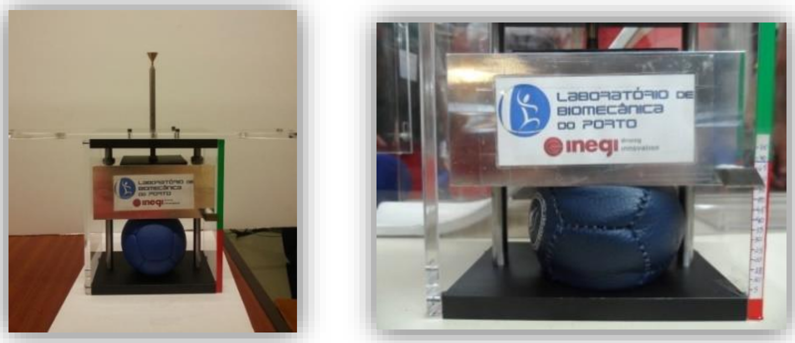

Figure 13– Ball deformability test

3.3 Results

When investigating the weight of the balls, we found that only one was not in accordance with the rules of the sport. It weighed less than 263 g, the minimum weight established for the Boccia ball. This ball was not excluded from the sample, since it was being used in competitions by the athlete without any problem. From the weight evaluation of our sample we conclude that the mean weight of the balls was 275.58 g ± 4.97 g. In the figure 14 are presented the results obtained for all the sample.

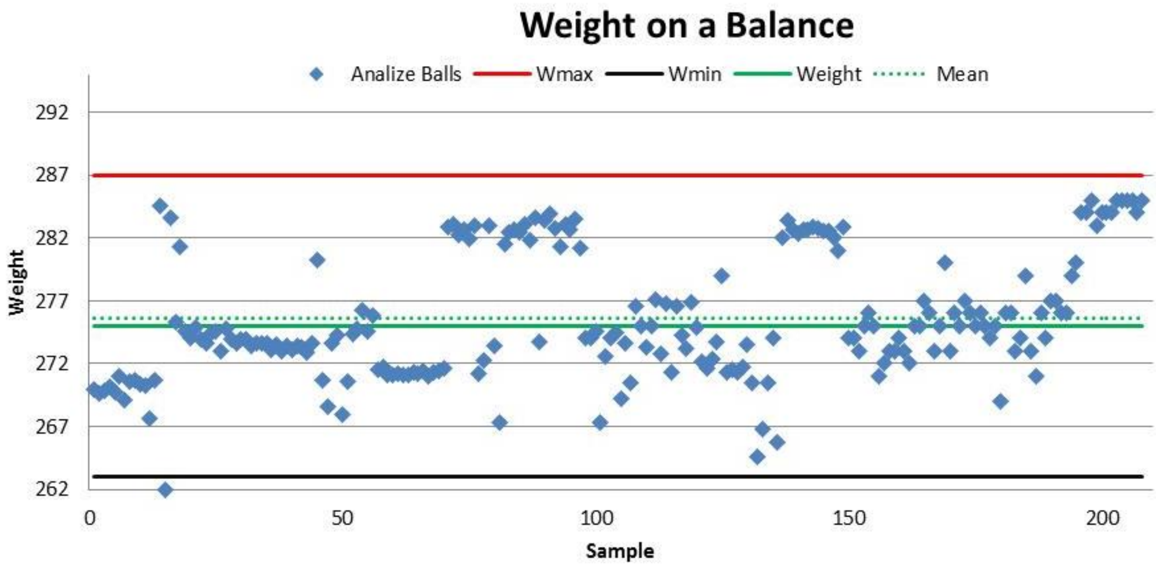

Figure 14 - Weights obtained for all balls on the sample

In testing the ball template according to the existing rules we can observe that only 2% were rejected, meaning that 5 balls are not in the standard established by these rules, which can be seen in figure 15.

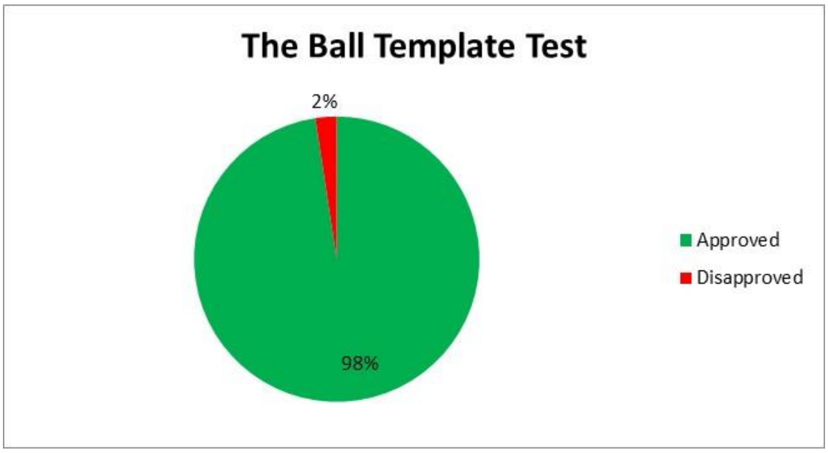

Figure 15 - Balls approved and disapproved in the ball template test

After measuring the diameter using the calliper Sanny, we use the formula $C = \pi d$ to find the value of the perimeter. Each ball diameter was measured three times, each one with the ball in a different position, and the mean of the three values was used as "the" ball diameter. Using this evaluation method we can realize that multiple balls would be considered as invalid for being below the value allowed which is 262mm (figure16).The average perimeter was 265,91 mm ± 3,38 mm.

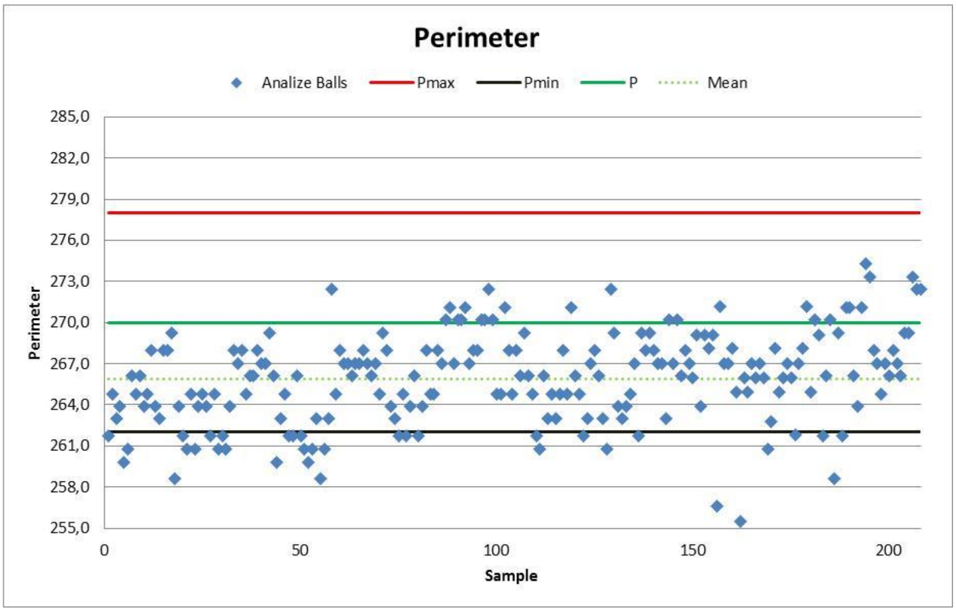

Figure 16 – Evaluation of the balls perimeter from the measurement of the diameter

All the elements of the sample were also submitted to the rebound test, where the balls bounced between 1cm and 24cm (figure 17). The value of the coefficient of restitution was obtained averaging 0.169 ± 0.05. For this test a total of 149 balls were evaluated (the remaining balls were not taken to the laboratory for technical reasons).

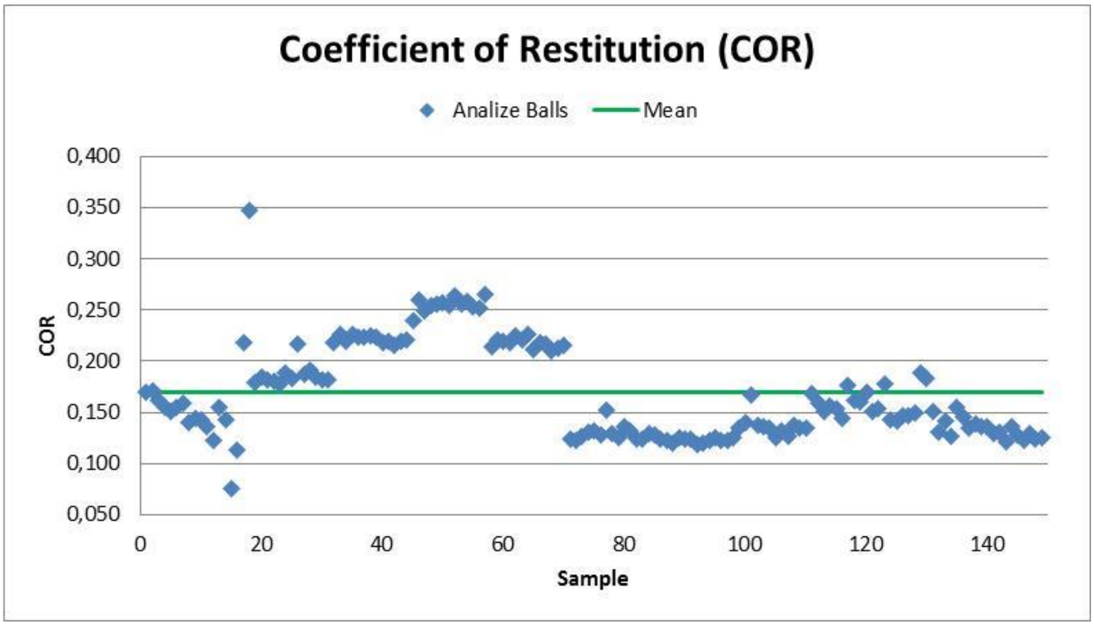

Figure 17 – Coefficient of Restitution obtained of the Boccia balls

In the ramp test it was found that not all the balls roll down in the rail with a slope of 12 degrees, being the red the best balls which registered only one exclusion, followed by 6 for the whites and 12 for the blues (figure 18).

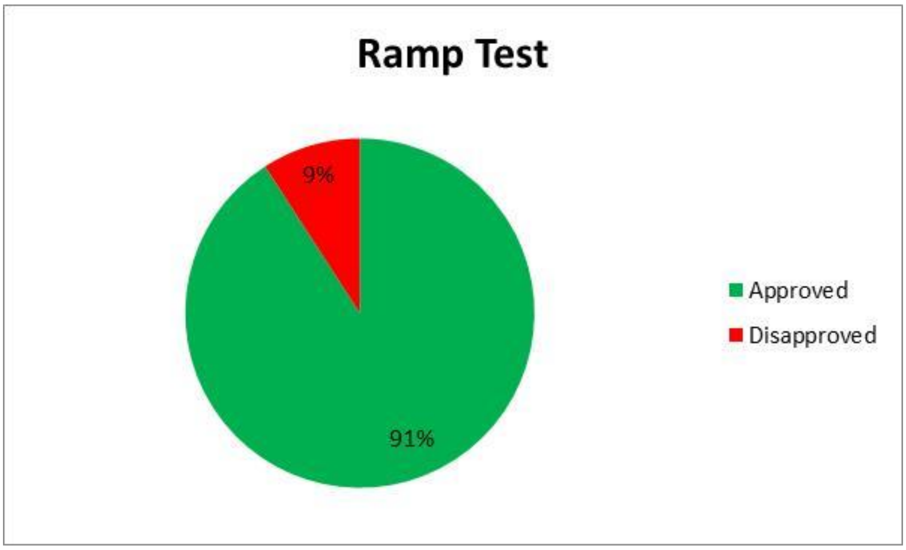

Figure 18 – Balls approved and disapproved in the ramp test

Associated to these results, it was also obtained a great number of exclusion in the stiffness (deformability) test. Among the disapproved balls on the ramp test, it was verified that they have less than 68 mm of deformation (figure 19). Therefore we established this figure as the limit in of value to accept or exclude a given ball.

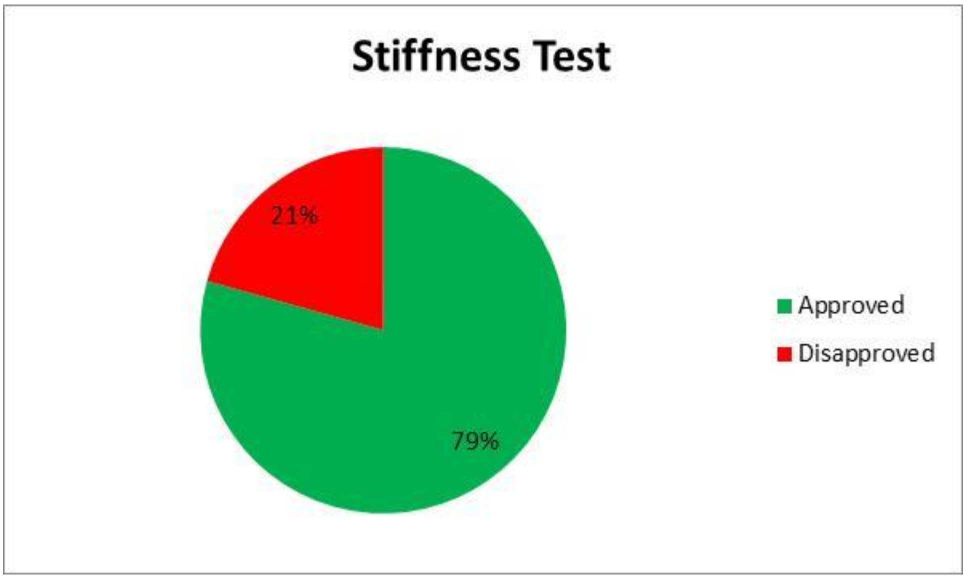

Figure 19 – Balls approved and disapproved in the stiffness test

In the graph shown in figure 20 we can see that several balls are far below our limit of acceptance. In the tested sample it was found extremely soft balls with stiffness of only 56 mm. The mean stiffness was 73,58 mm ± 6,52 mm.

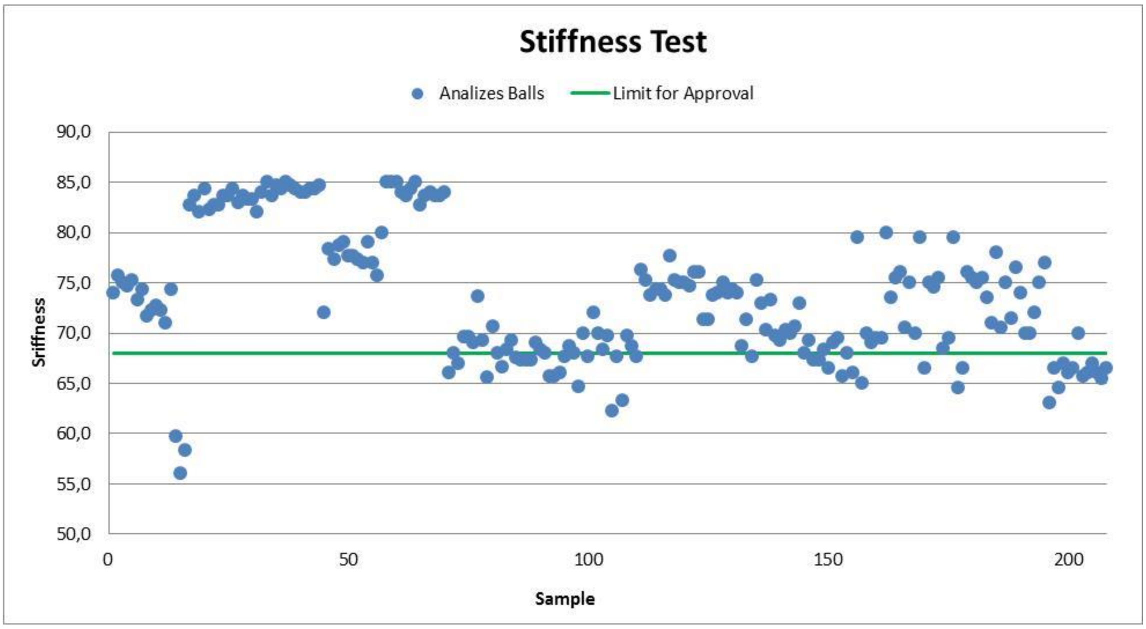

Figure 20: Stiffness obtained of the Boccia balls

From the whole sample, 7 white balls, 14 red balls and 22 blue balls fail which means 21% of the balls (figure 21). A justification with relation to a great number of disapproved balls particularly the blue ones, may be related to reaction of the ink with the skin type. The average stiffness of the test was 73,58 mm ± 6.52 mm.

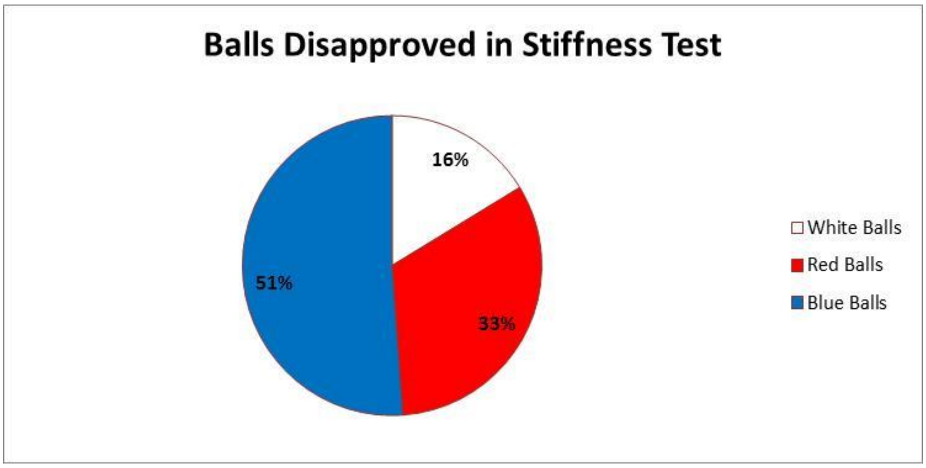

Figure 21: Percentage of disapproved balls according colors

In Figures 22 and 23 we compared the results of the balls approved in the mold for balls test, in the ramp test and the stiffness test. We had a high rate of approved balls in these tests although the values depend on the considered test.

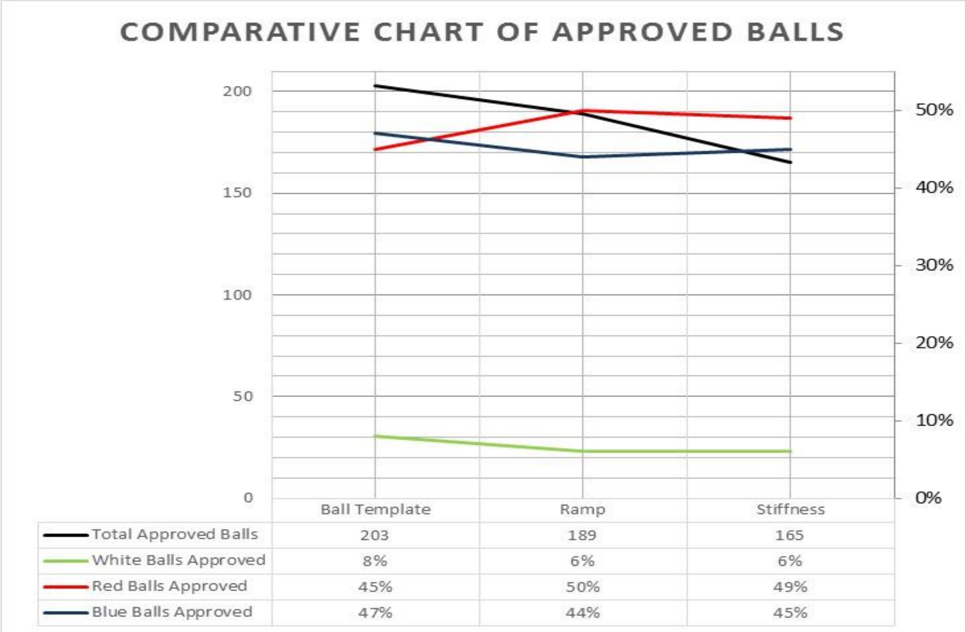

Figure 22 - Approved balls in mold test for balls, ramp and stiffness

We can also observe that in the mold for balls test 5 balls were disapproved, the majority of them being red. More balls were disapproved in the stiffness test than in the ramp test, and we observed that in these two tests the blue balls are the most disapproved.

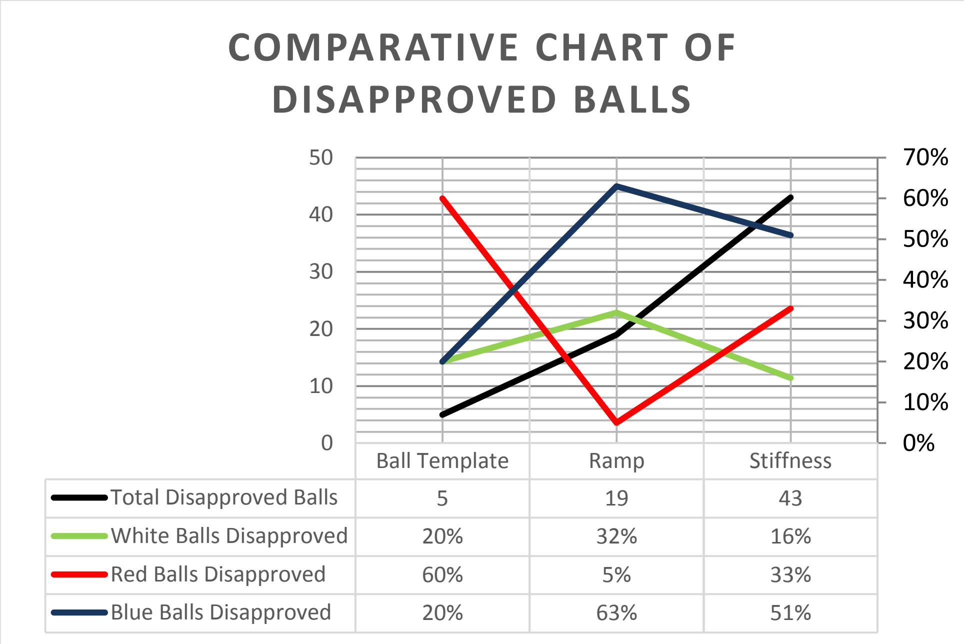

Figure 23 - Disapproved balls in mold test for balls, ramp and stiffness

There was only one ball of mass of 265 g that fail the test (Figure 24). This same ball also fails de ramp test, as well as the rigidity test. There was only one ball that failed the test showing a mass of 262g. This ball also fails the ramp test, as well as the rigidity test showing a value of 56mm, well below the threshold for approval. When looking for the perimeter result, we found that 32 balls were below the standard set by BISFed, which is 262 mm.

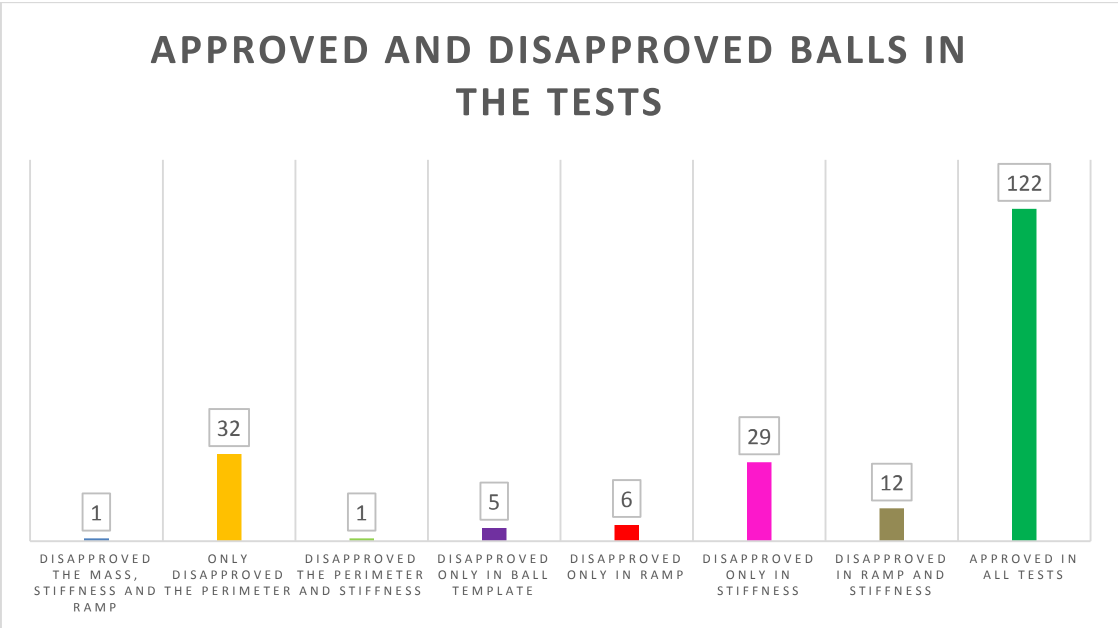

Figure 24: Approved and Disapproved balls in ramp test, perimeter, ball template and stiffness test.

In June 2014 during the Master Open held in Póvoa do Varzim we tested the ball stiffness from other countries/athletes by using this technique. During the contest period, different countries tested some balls of their athletes so that they confirmed the results obtained in our research, that the minimum value to have a ball approved is 68 mm. From a total of 334 balls, 233 were approved and 101 disapproved through this test (figure 25).

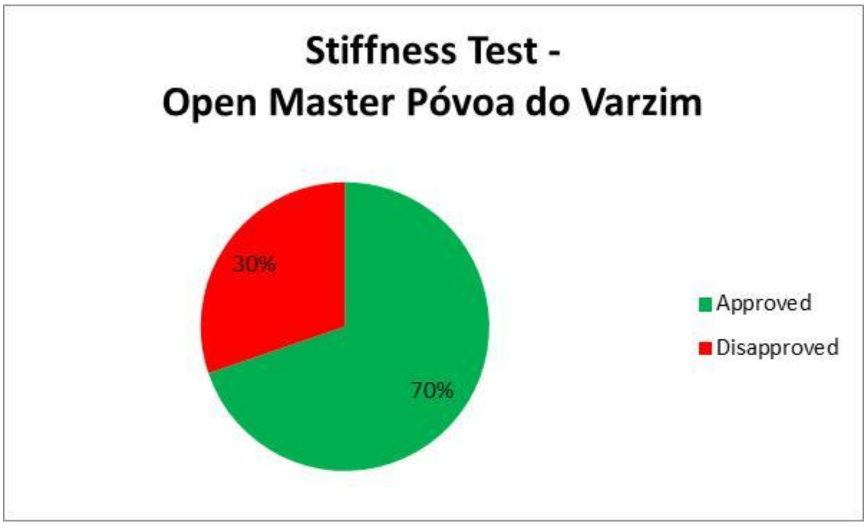

Figure 25: Percentage of approved and disapproved balls

Most of the players showed a good receptivity to the proposed test. However, some questions were raised about how to handling the test device by the user, i.e., the test depends on how the load is released. Since it is a test that is often repeated by the user, a new solution was designed to eliminate this problem of manual interference and was incorporated into a new version of the prototype.

Figure 26 shows the design in Computer Aided Design (CAD) of the new version where in the vertical rod was incorporated a pneumatic system that will allow a controlled downward velocity of the system to compress the ball.

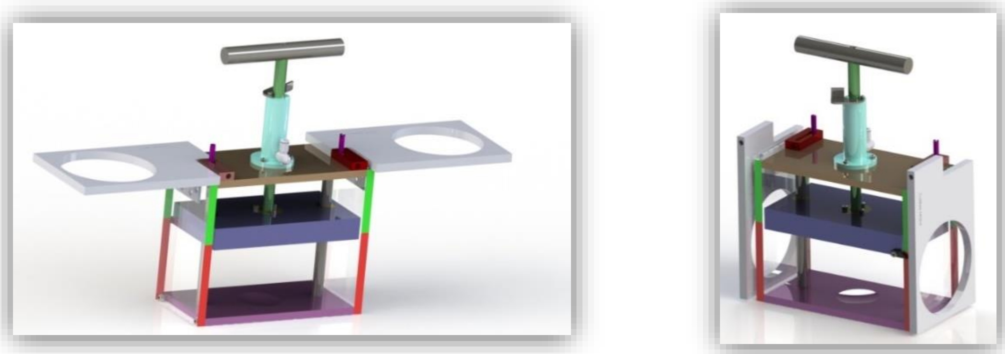

Figure 26 – New prototype for ball stiffness (deformability) measurement

With this new solution the human interference in the execution of the test is attenuated, making it more reliable with respect to the results.

3.4 Discussion and Conclusions

The purpose of this study was to evaluate the Boccia balls with simple and low cost tests, in order to regulate the characteristics of the balls used in the game. This study comes from a problem presented by the BISFed, which until March 2014 would have to introduce new procedures concerning the validation of the Boccia balls since athletes were bringing very soft balls that were changing the game evolution. The first tests performed in the lab, presented in May, during the competition World Open Event Montreal were related to the ramp test with a slope of 12 degrees. This test come as an answer to the requested question and because we were seeking a practical and simple test to be held during the competition while keeping the specificity of the game.

Considering that the energy required to roll the ball on the ground is an important variable in the game, a number of tests were set to further characterize the balls.

To propose a regulation for the balls characterization several tests were carried out. first the weight of the balls was assessed. The balls tested were in general within the range accepted by the BISFed although only one was out of this range with 263 g. Despite this result we did not exclude this ball from the sample because one athlete was using it during the competition. This result shows that the main difference is not related with the balls weight.

When looking to the perimeter using the ball template, we found that 5 new stiff balls failed the test, namely 1 white, 1 blue and 3 red, with a perimeter value greater than 278 mm. In these balls we verified that the seams were too lose causing the ball got stuck in the larger caliber, not allowing it to pass.

To measure the diameter of the balls, we used a caliper from Sanny. The results showed that some balls had smaller diameter than that established by the rule. This was because the balls were measured in three random positions, and thus we observe that the balls are not quite round, being found some clearly oval balls.

When comparing the results obtained by the caliper test, the one used by BISFed, with the diameter test, introduced in this study, it was found that there would be a greater number of disapproved balls if the later were performed. The obtained results showed a figure of 2% against 16% in favor of the diameter test concerning disapproved balls.

For the rebound test we used a system based on sound capture and through the ground impact we could compute its flight time and thus the height jumped. This test was adapted from the quality control test used by FIFA and also had some similarities to the one conducted by Dickson et al. (2010). Our results presented an amplitude from 1,15 cm to 24 cm being the very soft in the bottom line. This is a quite high amplitude reflecting a very big difference in the characteristics of the balls.

Over time the sample was being extended and we realized that the ramp test could suffer effects from other parameters such as: the skin type, the material inside the ball, the way of handling the ball to land it on the ramp, as well as the way how to drop the ball by the user. Since this test was performed by the same subject, it was tried to be accomplished in the same way.

It takes long to apply this test, since with each ball it should be carried out 5 times, and to be approved it would have to pass in 3 of 5 attempts. Taking into account that each athlete uses as minimum of 13 balls, with only one athlete the referee would have to perform 65 times the test. So, for all the reasons mentioned we chose to improve the stiffness test, which is a test for easy handling and larger reliability of the results.

Analyzing the results, we found that there is a wide disparity of values of coefficient of restitution. Just as in the rigidity graph, we can distinguish the new kits from the older ones by the results obtained from the COR graph. Thus we differentiate the new kits used, since most used kits have similar values. We can also observe that the same colour balls' may have a stiffness that may vary up to 10mm. This shows us that the balls have different mechanical properties.

In the stiffness test 29 balls were rejected, although 11 belonged to the same kit bocce, wherein all the balls were of the same brand. This brand shows an interesting feature, since new balls were already very soft, becoming quickly even softer. It was found that 6 balls showed a mass of 285g (near the maximum limit), although with a disapproval evaluation in the stiffness test, calling attention to the content inside the ball.

The stiffness test designed and developed in the Laboratory of Biomechanics of University of Porto (LABIOMEP) revealed that the balls have a greater deformation when they are placed on top of the seam. This is because in the manufacture process the balls have some skin sewn inside, then when the weight is on a slice, the plastic granules move away and get trapped in the seam. It is different if we land on the seam, because the plastic has more space to accommodate due the buds. When we took this test to the competition in Póvoa do Varzim, suggestions were made to eliminate the human interference in the manner of drop up the weight, because no matter how much you say that the weight should be landed slowly, a legal ball can be eliminated simply because the way on how the weight is landed. Therefore we developed a new prototype which eliminates this problem and is still reliable in the results as the previous prototype.

Thus, we believe that the new stiffness test can meet the needs to assess the Boccia balls, taking into account their mechanics properties, making it an easy and reliable test to apply.

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CHAPTER IV

EMPIRICAL STUDY II

PERCEPÇÃO TÁTIL DOS ATLETAS E ASSISTENTES EM RELAÇÃO À RIGIDEZ DAS BOLAS DE BOCCIA

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Resumo

Conhecer o equipamento de jogo é um factor importante para que o atleta possa obter um bom desempenho nas competições. No jogo de Boccia pode-se observar o domínio do atleta com as bolas, pois geralmente elas apresentam características diferentes. Pode-se citar por exemplo, a rigidez, pois geralmente a primeira bola que o atleta lança depois da bola branca é mais macia. Sendo assim, o objetivo deste trabalho é avaliar e comparar a percepção tátil dos atletas e assistentes em relação ao resultado do teste de rigidez do seu próprio kit de bolas de Boccia. Foram utilizados os resultados do teste de rigidez para comparar com a avaliação dos atletas e assistentes quanto a percepção tátil das bolas de Boccia. Os assistentes obtiveram um total de 41% de acertos, enquanto os atletas acertaram 36%. Os atletas acertaram 40% da sequência das bolas vermelhas, enquanto os assistentes acertaram 46% da sequência das bolas azuis. De acordo com a correlação de Spearman's Rho, foi detectado um nível considerável de falibilidade na determinação do nível de rigidez do teste percepcional, quando comparado com o teste experimental. Como feedback dos atletas quanto ao teste, eles marcaram novamente as suas bolas, baseados nos resultados do teste da rigidez.

Palavras – Chave: Bolas de Boccia; Rigidez; Percepção Tátil

4.1 Introdução

O Jogo de Boccia é composto por 6 bolas vermelhas, 6 bolas azuis e 1 bola branca. Nas bolas disponíveis no mercado podemos encontra-las com diferentes revestimentos, sendo em pele sintética, pele natural ou do tipo veludo. Dependendo do tipo e da rigidez da bola, o atleta pode ter diversas possibilidades de jogo.

No jogo de Boccia é comum vermos as bolas com algumas marcações, sejam elas com números ou símbolos, marcadas pelo próprio atletas/assistentes. Seja como for que a bola esteja marcada, a marca serve de indicação para o atleta, pois quando ele tem um certo tempo de treinamento, ele sabe o que pode fazer com cada bola, ou em que situações de jogo ela deverá ser utilizada.

A numeração usada muitas vezes varia de 1 a 6, sendo que alguns atletas marcam as bolas de forma aleatória, enquanto outros utilizam a bola 1 como a bola mais macia e assim sucessivamente, sendo a bola 6 a mais rija. Essa marcação é de fundamental importância para distinguir a bola mais macia, pois esta bola bem posicionada em frente da bola branca dificulta as ações do adversário, como também facilita para ficar posicionada em cima de outras bolas. Contudo não existem testes fiáveis para distinguir as bolas a não ser a palpação.

Chamamos de percepção tátil, quando utilizamos a mão ou qualquer outra parte do corpo para sentir e identificar algo. Para Kunzler (2003), com as terminações nervosas encontradas na pele, conseguimos sentir o frio, calor, textura, dor e pressão. Segundo Magill (2011), é nas pontas dos dedos que encontramos uma maior concentração de receptores.

Segundo Magill (2011), durante a execução de uma habilidade motora ao manipularmos um objeto, como por exemplo, pegar uma bola, consegue-se descobrir as suas características específicas através dos receptores sensoriais da pele.

Uma vez que utilizamos a mão para percepcionar, segundo Yoneyama (2012), *a informação tátil é importante para modular a amplitude da força muscular* *isométrica da mão de acordo com o peso e formato do objeto, e adaptar a pinça por meio da percepção do objeto pelo contato da mão durante a preensão.*

Uma lesão na medula pode acarretar na perda da sensibilidade e motricidade na área atingida (Costa et *al*., 2011) e segundo Gorgatti & Böhme (2008), o sistema autónomo também pode ser atingido. Estes autores ainda afirmam que dependendo do local afetado na coluna, como também o número de fibras destruídas, pode-se definir o grau da paralisia.

Alguns estudos em crianças com paralisia cerebral demostram que, elas podem apresentar deficiências na aprendizagem motora, sensorial e/ou cognitivas associadas (Sá et al., 2004).

Assim observamos que uma característica comum da lesão medular e da paralisia cerebral é que podem apresentar déficits no sistema sensorial. Por isso não determinamos um só modo de verificar a rigidez da bola pelos atletas, eles realizaram o teste de acordo com o que sua capacidade funcional o permitia fazer.

Sendo assim, este trabalho tem como objetivo avaliar e comparar a percepção tátil dos atletas e assistentes em relação ao resultado do teste de rigidez do seu kit de Boccia.

4.2 Materiais e Métodos

4.2.1 *Amostra*

A amostra é composta por atletas com Lesão Medular e com Paralisia Cerebral. Foram escolhidos aleatoriamente por meio de sorteio, 5 atletas e 5 assistentes, sendo eles, 1 atleta da seleção portuguesa de Boccia, 2 atletas que competem a nível nacional em Portugal e 2 atletas da seleção brasileira de Boccia. Obtivemos um total de 1 atleta da classe BC1, 2 atletas da classe BC2 e 2 atletas da classe BC3, como podemos observar na tabela 1 abaixo.

Tabela 1 – Amostra dos atletas e assistentes

Atleta/ Assistente	Tempo de Prática	Tempo de Prática juntos	Tempo do Kit de Boccia
Atleta 1 (BC 3)	10 anos	3 meses	3 anos
Assistente 1	3 meses		
Atleta 2 (BC 3)	6 anos	6 anos	1 ano
Assistente 2	6 anos		
Atleta 3 (BC 2)	15 anos	5 anos	2 anos
Assistente 3	5 anos		
Atleta 4 (BC 2)	15 anos	2 anos	6 anos
Assistente 4	2 anos		
Atleta 5 (BC 1)	13 anos	3 anos	3 anos
Assistente 5	8 anos		

4.2.2 *Metodologia*

No trabalho intitulado: "*Proposal for Regulations of the Boccia Balls*", foi desenvolvido um teste de rigidez "mamografia" que consiste em verificar a deformabilidade diametral (figura 1). Para testar a deformação da bola o dispositivo era composto por uma plataforma com uma régua de 0 a 100 milímetros de extensão e aplicado um peso de 22,5 N sobre a bola. Este peso foi definido de tal maneira que não afetasse as propriedades da bola.

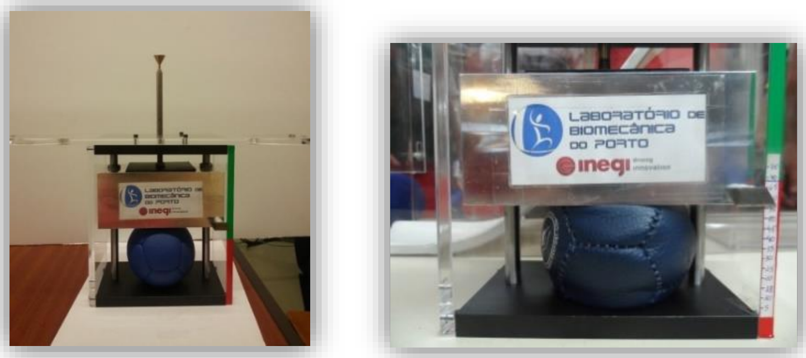

Figura 1 – Teste de Rigidez

Todas as bolas foram marcadas com etiquetas, cada uma com um código único que indicava a qual kit de Boccia pertencia, e com uma numeração aleatória, de modo a não influenciar os atletas e assistentes no momento da execução do teste. As bolas que cujo código iniciava-se com B eram as brancas, com V as vermelhas e com A as azuis.

No teste de rigidez, o avaliador verificou a altura inicial da bola em milímetros antes dela sofrer a deformação, e em seguida a sua deformação final, ou seja, após sofrer a deformação através do peso de 22,5 N. Após as medições calculamos o valor inicial menos o valor final da deformação ($\varepsilon = \varepsilon_i - \varepsilon_f$), e com estes resultados, as bolas foram ordenadas de forma crescente, a partir da que sofria uma maior deformação (as bolas macias), até às bolas que se deformavam pouco (as bolas rijas). As bolas foram separadas por cores (vermelhas e azuis), porém acrescentando a bola branca para ser avaliada juntamente com as duas cores. É importante ressaltar que esta sequência era do conhecimento exclusivo do avaliador, não sendo divulgada aos atletas e assistentes antes da realização do teste.

Sabemos que os atletas possuem mais bolas do que necessitam para o jogo. O teste de rigidez foi realizado com todas as bolas do kit, porém para o teste da percepção solicitamos aos atletas que usassem as bolas com que realmente jogam. Então foram selecionadas 6 vermelhas, 6 azuis e 1 branca por cada atleta.

O teste foi realizado com um atleta e o seu assistente por vez. Inicialmente pedimos ao atleta que ordenasse as suas bolas vermelhas e branca da mais macia até à mais rija. Registamos o resultado da sequência e depois o mesmo procedimento foi seguido com as bolas azuis e a branca. Em seguida foi realizado o mesmo procedimento com o assistente. Como a bola branca foi introduzida no teste duas vezes, i.e. com as vermelhas e com as azuis, foi contabilizado um total de 14 bolas por atleta/assistente.

Temos como exemplo da grelha do avaliador, os resultados do Atleta 5 e Assistente 5, nas tabelas 2 e 3:

Tabela 2 – Grelha do Avaliador para as bolas vermelhas e branca

Bolas Vermelhas + Branca								
AT 5	V05K9	B0K9	**V02K9**	V01K9	**V04K9**	V06K9	**V03K9**	**3 Acertos**
AS 5	**B0K9**	**V05K9**	**V02K9**	**V04K9**	V01K9	V06K9	**V03K9**	**5 Acertos**
Experimental	**B0K9**	**V05K9**	**V02K9**	**V04K9/V06K9**		**V01K9**	**V03K9**	

Tabela 3 – Grelha do Avaliador para as bolas azuis e branca

Bolas Azuis + Branca								
AT 5	**A01K9**	A03K9	B0K9	A02K9	A04K9	A06K9	A05K9	**1 Acerto**
AS 5	**A01K9**	A03K9	B0K9	**A06K9**	**A02K9**	**A05K9**	**A04K9**	**5 Acertos**
Experimental	**A01K9**	**B0K9**	**A03K9**	**A06K9**	**A02K9**	**A05K9**	**A04K9**	

Para finalizar, posicionávamos as bolas vermelhas e a branca na sequência estabelecida pelo atleta, e em seguida mostrávamos o resultado experimental obtido através do teste de rigidez. Para as bolas azuis e a branca também seguimos o mesmo procedimento. Em seguida realizamos o mesmo processo com os assistentes.

4.3 Resultados

Numa visão geral, os assistentes (AS) obtiveram 41% de acertos, enquanto os atletas (AT) 36%. Os AT 3 e 4, obtiveram mais acertos do que os seus respectivos assistentes, sendo assim os AS 1, AS 2 e AS 5 obtiveram mais acerto do que os seus atletas (figura 2).

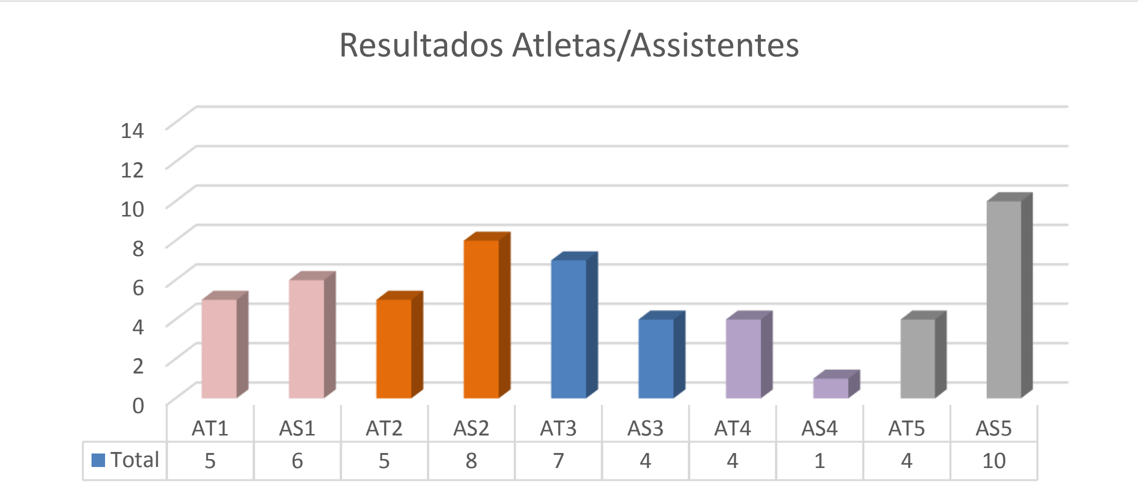

Figura 2 – Acerto dos atletas e assistentes no total, em relação as bolas vermelhas, azuis e branca.

Em relação aos resultados dos atletas da sequência do teste de rigidez, eles acertaram 40% das bolas vermelhas, enquanto nas azuis foram 31%. Na figura 3 podemos observar que os AT 3, AT 4 e AT 5, acertaram mais bolas vermelhas em relação ao resultados obtidos com o teste de rigidez.

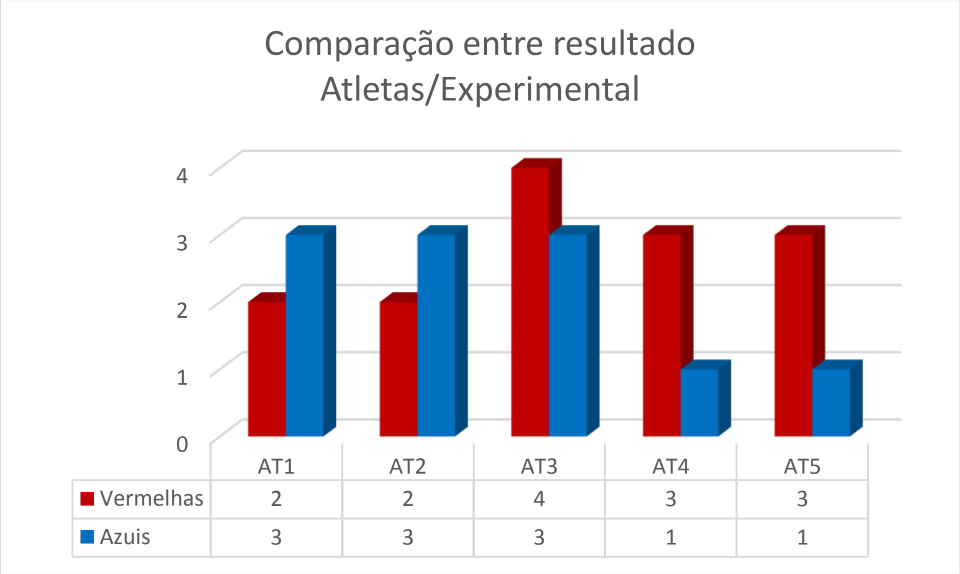

Figura 3 – Acerto da sequência de bolas Vermelhas e Azuis dos atletas.

Porém os AS 1, AS 2 e AS 5 obtiveram igual acerto das bolas vermelhas e azuis em relação ao resultado experimental (figura 4). Sendo que os AS 3 e AS 4 acertaram mais bolas azuis do que as vermelhas, sendo 37% de acertos das bolas vermelhas e 46% das bolas azuis.

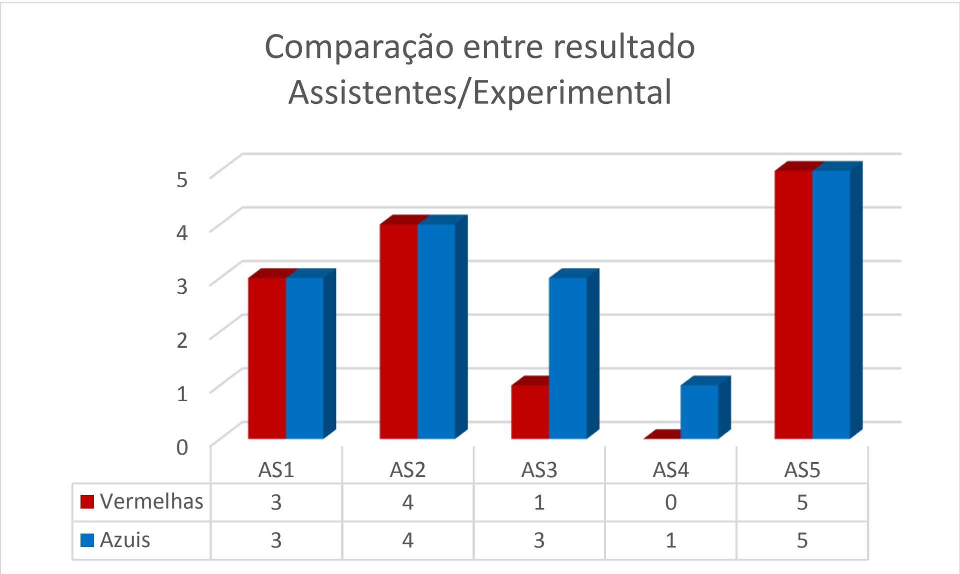

Figura 4 – Acerto da sequência de bolas Vermelhas e Azuis dos assistentes

Tabela 4 – Resultados amostrais da deformação das bolas azuis e vermelhas em mm por experimento

mm	VERMELHAS			AZUIS		
	$\bar{x}$Ɛ	σƐ	AƐ	$\bar{x}$Ɛ	σƐ	AƐ
BC3-EXP1	10,4	2,8	9	11,1	3,36	11
BC3-EXP2	*9,7*	*1,41*	*4,5*	*9*	*1,36*	*3,5*
BC2-EXP3	14,5	2,15	7,4	15,1	1,58	5,4
BC2-EXP4	*8,7*	*0,44*	*1,3*	*8,1*	*0,49*	*1,7*
BC1-EXP5	14,1	1,95	6	15,8	2,13	5,7
$\bar{x}$ TOTAL	11,48	1,75	5,64	11,82	1,784	5,46

Ɛ – deformação / $\bar{x}$ – média / σ – desvio padrão / A – amplitude

Na tabela 4 é possível observar a média ($\bar{x}$) das deformações apresentadas em mm de cada kit submetido ao teste experimental, subdivididos entre as bolas azuis e vermelhas, sendo ainda possível observar no EXP4 os menores valores médios de deformação ($\bar{x}$=8,7mm ±0,44 e 8,1mm ±0,49, vermelhas e azuis respectivamente) e os maiores valores médios no EXP3 ($\bar{x}$=14,5 ±2,15 – vermelhas) e no EXP5 ($\bar{x}$=15,8 ±2,13 – azuis).

Outro dado importante fornecido foi a amplitude (A), que representa a diferença entre a maior deformação e a menor, encontrada em cada kit avaliado. Esse parâmetro foi interessante para interpretar a margem de variação que os atletas e assistentes dispunham a quando do estabelecimento da ordem de rigidez através do processo tátil. A título de exemplo, enquanto no EXP1 as bolas vermelhas e azuis apresentaram uma amplitude de 9mm (σ= 9) e 11mm (σ=3,36), respectivamente, no EXP4 foram de 1,3mm (σ=0,44) e 1,7mm (σ=0,49).

Tabela 5: Correlações não-paramétricas de Sperman's Rho

	BOLAS VERMELHAS		BOLAS AZUIS	
	ρ	***p***	***ρ***	***p***
AT-AS-1	***,893*****	***,007***	,750	,052
AT-EXP-1	*,811**	*,027*	,703	,078
AS-EXP-1	,685	,090	***,919*****	***,003***
AT-AS-2	,500	,253	,714	,071
AT-EXP-2	,259	,574	,631	,129
AS-EXP-2	,519	,233	***,883*****	***,008***
AT-AS-3	***,893*****	***,007***	***,893*****	***,007***
AT-EXP-3	***,893*****	***,007***	***,901*****	***,006***
AS-EXP-3	*,786**	*,036*	*,757**	*,049*
AT-AS-4	,143	,760	*,857**	*,014*
AT-EXP-4	,546	,205	,200	,667
AS-EXP-4	,327	,474	,273	,554
AT-AS-5	***,929*****	***,003***	*,821**	*,023*
AT-EXP-5	*,847**	*,016*	*,786**	*,036*
AS-EXP-5	***,937*****	***,002***	***,964*****	***10^{-3}***

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Com base na utilização do teste não-paramétrico de Spearman's Rho (ρ) observa-se que AT1 apresenta, em relação às bolas vermelhas, forte correlação linear estatisticamente significativa positiva com AS1 (ρ=0,893**) para um nível de significância (p=0,007) elevado, situação semelhante ocorre nos casos entre o AS1 e o EXP1 (ρ=0,919**; p=0,003), o AS2 e o EXP2 (ρ=0,883**; p=0,008), relativos às bolas azuis, entre o AT5 e o AS5 (ρ=0,929**; p=0,003), quanto as bolas vermelhas. As correlações entre AT3-AS3, AT3-EXP3 e AS5-EXP5 seguem o padrão descrito nas situações anteriores para ambas as bolas, vermelhas (ρ=0,893**; p=0,007 / ρ=0,893**; p=0,007 / ρ=0,937**; p=0,002) e azuis (ρ=0,893**; p=0,007 / ρ=0,901**; p=0,006 / ρ=0,964**; p=10^{-3}).

Igualmente, foram verificadas correlações lineares estatisticamente significativas positivas a nível de significância abaixo de 0,05 nos seguintes casos: AT1-EXP1 (ρ=0,811*; p=0,027) em concernente as bolas vermelhas, AT4-AS4 (ρ=0,857*; p=0,014) e AT5-AS5 (ρ=0,821*; p=0,023) quanto as bolas azuis. Ainda foram representativas as associações AS3-EXP3 e AT5-EXP5, tanto para vermelhas (ρ=0,786*; p=0,036 / ρ=0,847*; p=0,016), quanto para azuis (ρ=0,757*; p=0,049 / ρ=0,786*; p=0,036), respectivamente, porém essas últimas tendendo ao limite da significância.

Dentre os resultados, 13 (treze) apresentaram correlações muito baixas (ρ<=0,750) para um nível de significância de p>=0,052, sendo eles: AT1-AS1 (ρ=0,750; p=0,052), AT1-EXP1 (ρ=0,703; p=0,078), AS1-EXP1 (ρ=0,685; p=0,090), AT2-AS2 (ρ=0,500; p=0,253 / ρ=0,714; p=0,071), AT2-EXP2 (ρ=0,259; p=0,574 / ρ=0,631; p=0,129), AS2-EXP2 (ρ=0,519; p=0,233), AT4-AS4 (ρ=0,143; p=0,760), AT4-EXP4 (ρ=0,546; p=0,205 / ρ=0,200; p=0,667), AS4-EXP4 (ρ=0,327; p=0,474 / ρ=0,273; p=0,554).

Na comparação entre as percepções táteis dos atletas X assistentes houve um equilíbrio no nível de significância dentre as possibilidades do estudo, apresentando 5 (cinco) delas uma correlação linear acima de ρ>=0,821* e p<=0,023, as outras 5 (cinco) encontram-se aquém daquela correlação e além do nível de significância.

4.4 Discussão/Conclusão

O objetivo deste estudo foi confirmar se as marcações efetuadas pelos atletas e assistentes em função da sua percepção tátil, coincidiam com aquelas obtidas através de um método experimental baseado na determinação da rigidez, uma vez que a palpação consiste numa avaliação subjetiva.

Através deste estudo foi possível constatar que a diferença da deformação entre a bola mais macia e a mais rija nos kits testados variou em alguns casos em cerca de 11 milímetros. Variações desta magnitude permitem-nos distinguir os extremos, i.e. a bola mais macia vs a mais rija. Porém diferenciar as bolas intermédias resulta numa tarefa difícil, uma vez que as diferenças na rigidez nestes casos situavam-se em torno de 1mm em algumas bolas.

Na execução do teste, os dois atletas da classe BC3, percepcionaram a rigidez da bola através do queixo, ou seja, o assistente segurava a bola próxima ao queixo do atleta e com o movimento da cabeça eles pressionavam a bola. Um desses atletas confirmava sempre a numeração que já estava na bola antes de a colocar na sequência que foi solicitada. Nestes dois casos, os assistentes obtiveram um maior acerto da rigidez do que os atletas.

Enquanto os atletas obtiveram maior acerto com as bolas vermelhas, os assistentes foram melhores com as bolas azuis. Isso pode ter acontecido devido ao facto de sempre termos começado a avaliação com as bolas vermelhas, e por alguns assistentes terem modificado o seu método de avaliar quando passaram para as bolas azuis.

No decurso desta pesquisa tanto atletas como os assistentes manifestaram surpresa pelos resultados obtidos uma vez que confiavam nas suas capacidades tatéis. Observamos que habitualmente qualquer um destes intervenientes falhavam na sequência de colocação das diferentes bolas no resultado percepcional, o que pode ser observado nos resultados obtidos. Uma bola em que tanto os atletas como os assistentes estavam convictos que acertariam no resultado era a bola 1, ou seja a mais macia no teste percepcional.

Um dos grandes objetivos deste estudo foi o de avaliar se um teste efetuado com recurso a percepção sensorial permitia a obtenção de resultados semelhantes aos obtidos com recurso a um teste experimental. Para tal recorremos ao teste não-paramétrico de Spearman's Rho o qual não revelou correlações lineares negativas, implicando que não houve inversões entre os resultados apontados no teste experimental em comparação com os obtidos pelos testes perceptivos táteis de atletas e assistentes, nem na comparação destes últimos entre si.

O facto de não ter sido verificado o ρ negativo indica que quando feitas as comparações não houveram resultados inversamente proporcionais, isto é, não ocorreram resultados onde uma variável tendia a rigidez mais elevada e a outra apresentava-se mais tênue.

Considerando o valor de p em 0,025 como nível de significância com uma fidedignidade satisfatória para a comparação entre o resultado obtido no teste experimental e aqueles oriundos das percepções táteis dos atletas e assistentes, têm-se a frequência de 07 (sete) ocorrências dentre 20 (vinte) engendradas no presente estudo. Esse resultado demonstra a falibilidade da mensuração do nível de rigidez das bolas através do processo palpatório quer seja por atletas, assistentes, treinadores, árbitros, enfim, por qualquer meio da intervenção humana.

Nos resultados apontados por atletas, assistentes e as decorrências experimentais, separando-se os 02 (dois) conjuntos avaliados, bolas vermelhas e azuis, não se observam grandes diferenças, do ponto de vista estatístico, pelo fato de terem sido encontradas 08 (oito) correlações estatisticamente significativas dentre as 15 possíveis das bolas vermelhas e 09 (nove) para o caso das azuis. Para este estudo específico não foi possível estabelecer qualquer resultado relevante quanto à diferenciação das bolas de jogo, naquilo que concerne às cores, resultado ratificado pelos valores absolutos de deformação (Ɛ) para bolas vermelhas ($\overline{x}$=11,48mm; ±1,75mm; A=5,64) e bolas azuis ($\overline{x}$=11,82mm; ±1,78mm; A=5,46). Até porque outras características da bola foram desprezadas, como material de confecção, quantidade de gomos, tipo de costura etc., sendo consideradas e mensuradas o nível de deformação e de rigidez aferidos através da experiência.

Uma observação dos resultados obtidos evidenciam que o AT2 e AT4 não apresentam diferenças estatisticamente quando se compararam as vertentes estabelecidas para o efeito nomeadamente em AT2-AS2-EXP2 (ρ= 0,500 /0,714 / 0,259 / 0,631 / 0,519; p= 0,253 / 0,071 / 0,574 / 0,129 / 0,233; respectivamente) e em AT4-AS4-EXP4 (ρ= 0,143 /0,546 / 0,200 / 0,327 / 0,273; p= 0,760 / 0,205 / 0,667 / 0,474 / 0,554; respectivamente) e consequentemente obtiveram as menores variações nas comparações, mantendo-se a deformação (Ɛ) abaixo dos 10mm tanto para as vermelhas (EXP2 – Ɛ=9,7; σ=1,41; A=4,5 / EXP4 – Ɛ=8,7; σ=0,44; A=1,3) quanto para as azuis (EXP2 – Ɛ=9; σ=1,36; A=3,5 / EXP4 – Ɛ=8,1; σ=0,49; A=1,7). Ambos os dados descritos através do teste experimental sugerem, neste trabalho, uma maior dificuldade em medir a rigidez da bola através da percepção tátil à medida que diminui a amplitude de deformação, ou seja, a capacidade sensorial humana em detectar o nível de rigidez e a amplitude de deformação expressa pelo teste experimental específico constituem-se como variáveis inversamente proporcionais. Com isso pode-se inferir que avaliar o nível de rigidez das bolas de Boccia por meio do processo palpatório ou outro meio sujeito a subjetividade humana parece não satisfazer os requisitos necessários para uma correta distinção do nível de rigidez das bolas mesmo quando os atletas têm uma longa experiência e familiarização com elas. Os resultados apresentados mostram que para ser considerado satisfatório, a diferença entre a deformação das bolas deve ser discrepante, facto não observado quando se trata de aferições ao nível de poucos milímetros.

Deste modo, acreditamos que melhor do que mostrar aos atletas o resultado do teste de rigidez seria mais interessante a realização do teste da percepção tátil. Como objetivo final, os atletas marcaram novamente as suas bolas, baseados no teste da rigidez. Os atletas BC3 por exemplo, pediram para confirmar a nova sequência das bolas durante os treinos. E recebemos o feedback que os resultados do teste experimental estavam corretos.

4.5 Referências

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CHAPTER V

CONCLUSION

5.1 Conclusion

This study addressed the characteristics of the Boccia balls and their behavior when they are subjected to certain tests, and thus evaluate their mechanical properties. It also addressed the tactile perception of athlete and assistant in relation to their Boccia kit with the stiffness test.

Our main conclusions of this study:

• The test of stiffness satisfies the need to evaluate the Boccia balls, considering their mechanical properties.

• The majority of the balls rejected in the test of the ramp as well as in the test of the stiffness were of blue color.

• We were able to distinguish kits of Boccia balls of some athletes related to the weight, coefficient of restitution and stiffness.

• The test of rigidity assists during the training for the marking of the sequence of balls, from the softer to the firmer.

5.2 Suggestions for future studies:

After completing this study, we suggest some possibilities for future research in the area of Boccia. Thus we present some research hypotheses.

• Increase the number of balls in the sample with more possible diverse characteristics.

• Divide the results by classes (BC1, BC2, BC3 and BC4) to a more specific comparison between them.

• Increase the number of sample of athletes and assistants in the tactile perception test.

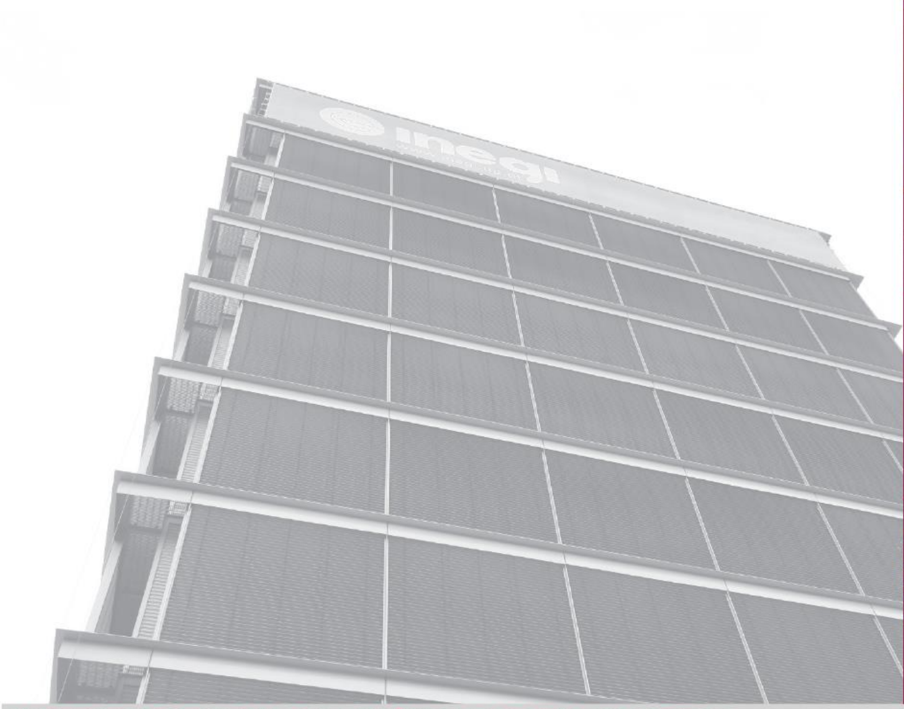
CHAPTER VI

ATTACHMENT

Attachment 1

since 1986

inegi driving innovation



INSTITUTO DE ENGENHARIA MECÂNICA E GESTÃO INDUSTRIAL
INSTITUTE OF MECHANICAL ENGINEERING AND INDUSTRIAL MANAGEMENT

LABORATÓRIO DE BIOMECÂNICA DO PORTO

Proposal for Regulations of the Boccia Balls

U.PORTO

0 Document Control

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Document File Name	Boccia

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0.3 Author(s)

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0.4 Reviser(s)

Name	Initials
Mário Vaz	MV
Tânia Bastos	TB
Filipe Conceição	FC

0.5 Distribution List

Nome	Initials	Entity
Federação Portuguesa de Desporto para Pessoas com Deficiência - Boccia	FPDD	Portuguese Sports Federation for Persons with Disabilities – Boccia
Comité Paralímpico de Portugal	CPP	Paralympic Committee of Portugal
Paralisia Cerebral-Associação Nacional de Desporto	PC-AND	Cerebral Palsy – National Association of Sports
Boccia International Sport Federation	BISFed	Boccia International Sport Federation
Faculdade de Desporto da Universidade do Porto	FADEUP	Faculty of Sports – University of Porto

1 – INTRODUCTION

The research here presented was elaborated by the request of the BISFed's President of the Committee of Development Helena Bastos through the Biomechanics Laboratory of the Universidade do Porto, (LABIOMEP), aiming to develop a method of evaluation of the mechanics properties of the Boccia's balls.

This evaluation seeks to answer a question regarding the problem felt in recent years due to a constant change in the characteristics of Boccia balls. Several teams have changed the initial structure of the Boccia ball to obtain advantages for their athletes. These changes have influenced the game, stripping out the beauty of it, but above all creating competitive imbalances that do not necessarily provide the best performance of athletes.

2 – EVALUATION OF BALLS

Since the Boccia balls are a decisive equipment of the game, their mechanical properties, geometric characteristics and its exterior texture are very important in sporting results. Thus, the teams try to adjust these properties for the game according to the player's needs. It is necessary to control the manipulation of the balls in order to ensure justice and equality among all contestants.

Given this possibility of manipulation of the balls, there have been very heterogeneous balls, specifically softer balls, which present a higher mechanical deformation. Although the level of deformability of the balls is acceptable for athletes may have different options depending on the game strategy. In the case of excessively soft balls, there is a distortion of the essence of the game by preventing the balls from rolling on the ground, jeopardizing the competition. The great deformation of the balls allow lowering its center of gravity, causing the increase of the contact area with the floor that allows them to absorb the impact energy of the other balls so that they do not roll or they can perform small displacements. In this case the athlete after placing one of these balls conveniently knows that the opponent hardly will be able to undo the move.

In Figure 1 presents two balls with the characteristics mentioned above. It should be noted that according to the current rules of 2013, which only control the weight and diameter, these balls would be accepted for competition.

Figure 1 - Boccia Balls Currently Used.

In order to remedy this situation the LABIOMEP defined a set of tests to fully characterize the properties of the balls in use. The tests used were the following:

•Weight Verification (Figure 2): We used a KERN - PLS scale style with 0.01g accuracy. Three measurements were performed

Figure 2 - Weight Verification

• Test of the Ball Template (Figure 3): 3 measurements were performed at different positions of the ball in each caliber.

Figure 3 - Test of the Ball Template

• Diameter Verification (Figure 4): We used a caliper from the brand Sanny to measure the exact value of the diameter in millimeters. Three measurements were performed at different positions of the ball.

Figure 4 - Diameter Verification

• Rebound Test (Figure 5): Measure the coefficient of restitution on impact with the ground. Three measurements were performed at the same height but at different positions drop the ball.

Figure 5 - Rebound Test

• Test of the Acrylic Ramp on a slope of 12 degrees (Figure 6): This test was suggested by coach Roberto Filipe and built by INEGI. is measured at rolling resistance on an incline surface. Five measurements were performed at different positions of the ball.

Figure 6 - Ramp Test

• Stiffness Test (“mammography”) (Figure 7): This test was developed and built by INEGI. Is measured at diametrical deformability (stiffness). Three measurements were performed at different positions of the ball.

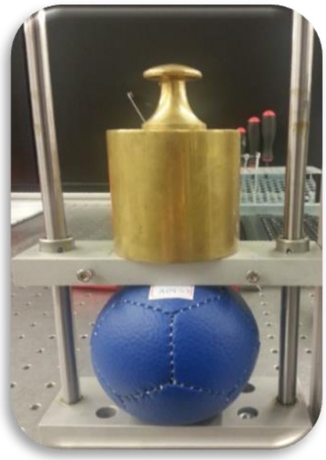

Figure 7 - Stiffness Test

To test the ball deformation the device consists in a rig with a millimetre rule spanning from 0 to 100mm and a mass weighting 22,5 N was used. This weight was defined in such a way that it does not affect the properties of the ball.

Until the present moment 542 balls have been evaluated. Initially 208 balls of different brands and in different athletes were evaluated, with the same national and international level, and belonging to some national and international selections of Boccia were evaluated. After statistical treatment of the data obtained, we verified that among the tests we performed, the stiffness diametrical test is the one with the best reliability, thus obtaining a more accurate and precise results.

In a second phase we improved our initial prototype and build this new one of the stiffness test (Figure 8) for evaluation of Boccia balls during the *Boccia World Open in Povoa de Varzim* which happened between June 18 and 23 of 2014. During the event 334 balls of athletes from different countries who attended this competition were evaluated.

Figure 8 - CAD Drawing and prototype built by LABIOMEP to evaluate the diametrical deformation (stiffness) Boccia ball.

During the championship in Póvoa de Varzim, this prototype was presented to the vast majority of athletes and officials.

Most of the teams in the championship manifested a good receptivity to the proposed test. However, questions have been raised concerning the form of handling by the referee. Therefore the test depends on how the load is released. Since it is a test that is often repeated by the referee, was thought a solution to eliminate this problem of manual interference that will be incorporated into a new version of the prototype.

Figure 9 shows a design in CAD (Computer Aided Design) where the new version of the vertical rod will incorporate a pneumatic system which will allow a controlled descent speed.

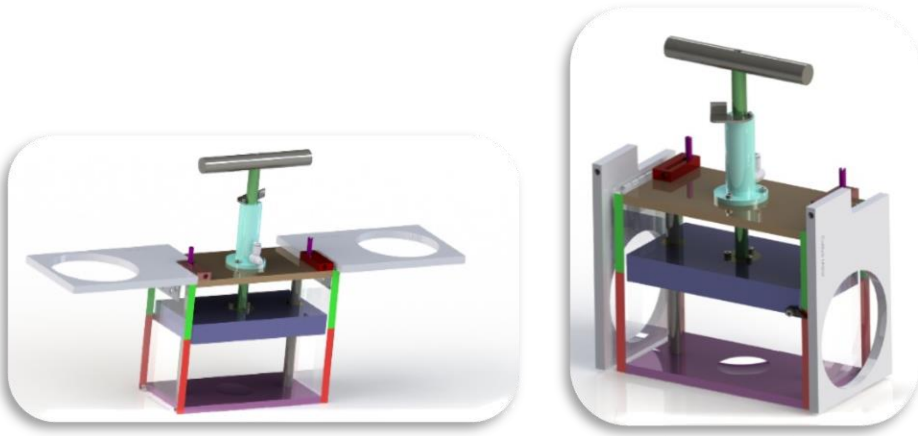

Figure 9 - New Version of the Prototype

According to studies conducted in LABIOMEP / INEGI so that a ball is approved, the vertical displacement of the weight must be equal or superior to the limit of 68 mm. Although this result has been obtained based on the statistical results already available in LABIOMEP / INEGI, we are open to suggestions that other countries and / or international federation of Boccia may present regarding others normative values if properly justified.

3 – RESULTS

Selected some important results and we can see that in Figure 10, we found that only one was not in accordance with the rules of the sport, it weights lesser than 263 g (2,58 N) the minimum weight established for the Boccia ball.. This ball was not excluded from the sample, since it was being used in competitions by the athlete without any problem. From the weight evaluation of our sample we conclude that the mean weight of the balls was 275.58g ± 4.97g.

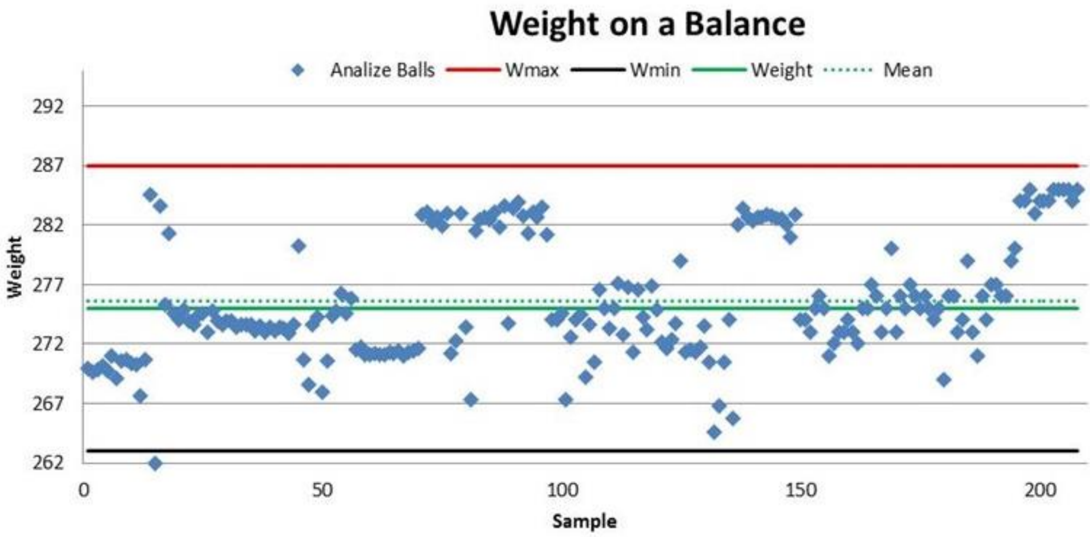

Figure 10 - Weights obtained for all balls on the sample

Then in Figures 11 and 12 compare the results the balls approved in the mold for balls test, in the ramp test and the stiffness test. We found that we had a high rate of approved balls in tests although the values depend on the test considered.

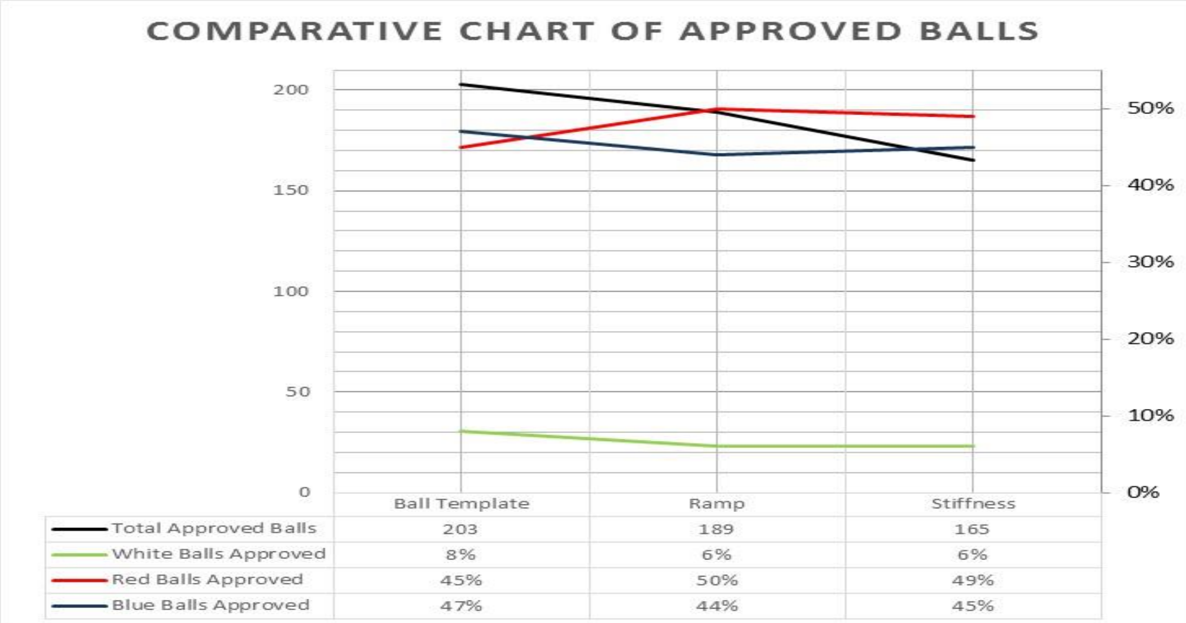

Figure 11 - Approved balls in mold test for balls, ramp and stiffness

We can also observe that in the mold for balls test, disapproved 5 balls, the majority of them being red. Were disapproved more balls in the stiffness test than the test of the ramp, and we observed that these two tests the blue balls are the most disapproved.

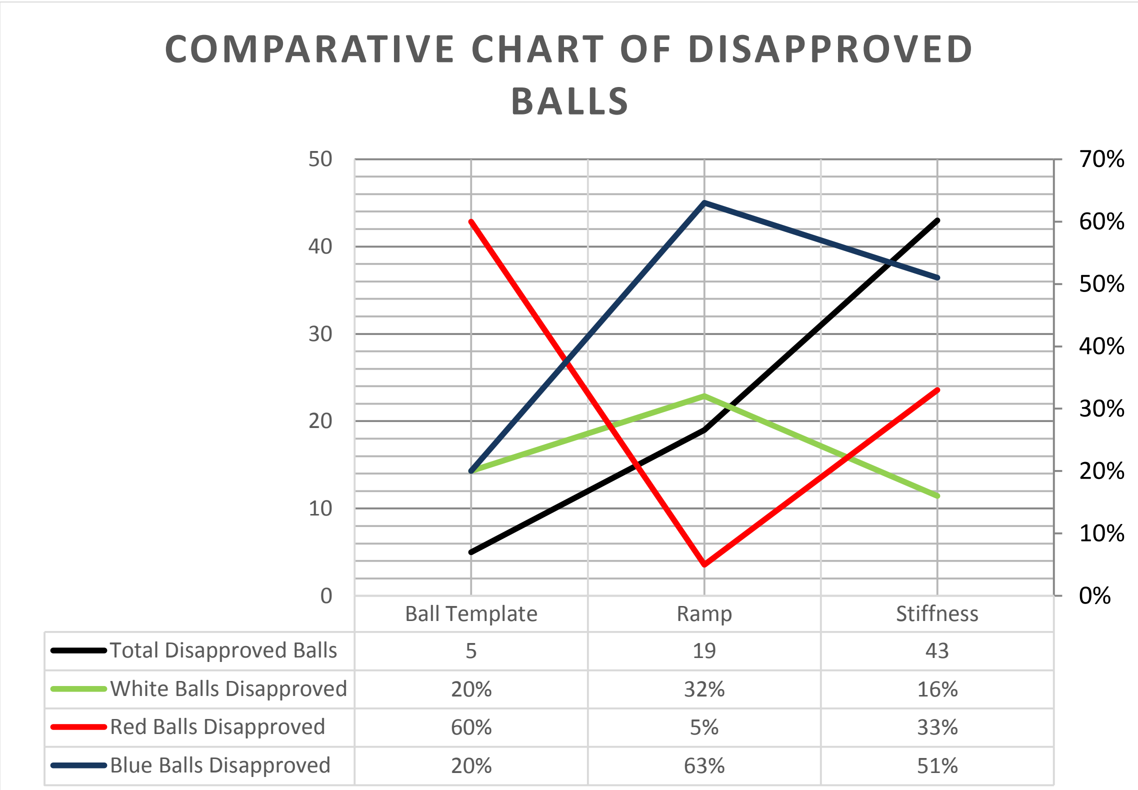

Figure 12 - Disapproved balls in mold test for balls, ramp and stiffness

4 – CONCLUSIONS

Assessments undertaken in the laboratory and in the competition already mentioned we believe that the stiffness test fits the current requirements of the sport. Since this is a static measurement avoids any influence caused by the interaction between the surface of the ball and the floor. If the fall's speed of the weight is controlled the influence of the operator is significantly reduced.

When compared with the current proposals under discussion, this method seems to us largely superior in terms of handling as well as in terms of reliability. Using the prototype will sort the balls according to their deformability: hard, soft and very soft. This ordinance was tested successfully with some of the top athletes of the national and international teams.

The work already accomplished is part of a master's thesis in Adapted Physical Activity, Faculty of Sport, University of Porto, and will be the object of a scientific presentation at the European Congress of Adapted Physical Activity, held in Madrid between September 29th and October 2nd of 2014.

We hope this work have contributed to make the competition fair, certainly avoiding paths that lead to competitive disadvantages.

Evidently, as is the evolution of the sport our main concern, we are open to suggestions and sharing ideas with all field researchers.

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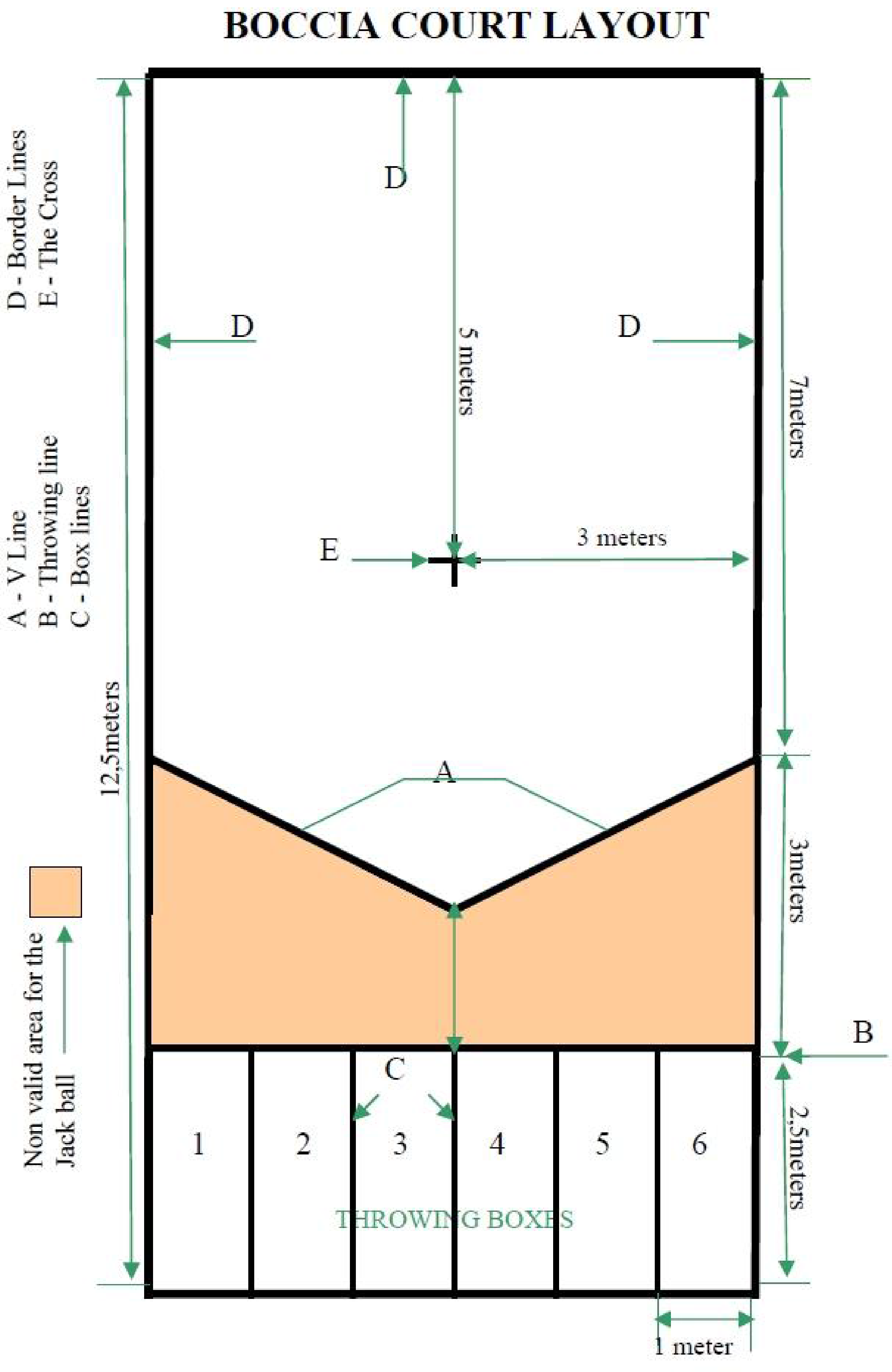
Attachment 2



Boccia Court Layout – Retirado do Boccia Rules (BISFed 2013)

Attachment 3

Percepção do Atleta e Assistente com as bolas de Boccia

Nome do atleta:___________________________________

Classe: _______

Tempo de prática: __________

Tempo de prática com o assistente: ___________

Tempo que está utilizando o kit: ___________

1. Numere na ordem as bolas que são mais macias até a mais rija.

Resultados:

Bolas Vermelhas:

Atleta									__ Acertos
Assistente									__ Acertos
Experimental									

Bolas Azuis:

Atleta									__ Acertos
Assistente									__ Acertos
Experimental									