Describing the Physical and Cognitive Determinants of Performance in Goalball players.

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The candidate confirms that the work submitted is their own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

This study was conducted to investigate the physical and cognitive characteristics of Goalball and whether the characteristics had a significant difference on Goalball performance and whether the significant characteristics differed between levels of performance. The aim of this research was to identify the physical characteristics applicable to Goalball and whether cognition also influenced performance. Coaches may then use these tools to identify the athletes with potential to be elite and can place athletes into groups based upon their physical attributes. It will aid in the conditioning of athletes and the recruitment process. Twenty-five UK Goalball athletes participated in this study. Of these athletes, ten were High-Performance athletes, five were Talent athletes and ten were Academy athletes. Participants completed testing on one occasion and this included tests which focused on Sprint performance, Aerobic capacity, Shoulder strength, Maximal strength, Core stability, Lower limb Power and Cognition. Data was analysed through Jeffreys Amazing Statistic Programme (JASP), and a one-way ANOVA was completed for all tests as well as a post-hoc Bonferroni test. Findings found that Lower limb Power, Sprint performance, Maximal strength, Shoulder strength and Core stability were all significant characteristics in relation to Goalball performance. This thesis highlighted the importance of training physical characteristics relevant to Goalball. These characteristics can enhance performance and help athletes become elite in Goalball which would in turn help with competition success. It may also help coaches to optimize training plans to improve performance. Future research is required to deeply investigate characteristics of Goalball on a larger scale to increase generalization of results. Higher sample sizes may have a more positive difference on results as well as ensuring all levels of performance conduct each test to see if there is a significance between more groups which was not possible in this thesis.

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List of Abbreviations

Visually impaired	VI
Isometric Mid-Thigh Pull	IMTP
Counter Movement Jump	CMJ
Athletic Shoulder Test	ASH
Sports Concussion Appraisal Tool 6th version	SCAT 6
Jeffreys Amazing Statistic Program	JASP
Maximum rate of oxygen consumption	VO_2 Max
Montreal Cognitive Assessment	MoCA
Adenosine Triphosphate	ATP
Brockport Physical Fitness Test	BPFT
Repetitions	Reps

1.0 Introduction

In 1946, Sepp Reindle and Hanz Lorenzen introduced a new sport for blind war veterans in rehabilitation (Petrigna *et al.,* 2020). This sport curated for largely blind war veterans was called Goalball. The sport grew significantly all over the world and Goalball made its official debut at the 1976 Toronto Paralympic Games (Yildirim *et al.,* 2013). This was followed two years later with the first World Championships in Austria, 1978, with the women's event being introduced to the 1984 New York Paralympic games, making Goalball an inclusive sport worldwide (Floyd and Mowling, 2019). Goalball is currently the most played sport among visually impaired (VI) athletes (Rich *et al.,*2022). There are currently 33 active UK Goalball teams in the UK (Goalball UK, 2022). The IBSA world rankings showed 303 male athletes, and 240 female athletes participating in the highest level of Goalball worldwide (International Blind Sport Federation, 2024). With Goalball being a fast-growing sport in both the UK and worldwide, it is important that further research into the depths of Goalball commences. Research into Goalball is needed to grow the game further and encourage more people with VI to get involved in physical activity.

1.1 Background to Goalball

The game requires many skills such as blocking, passing, throwing, rolling and ball control (Floyd and Mowling, 2019). The notion behind Goalball is to attack and score goals by shooting the ball across the court. Athletes then must defend by preventing opposition from scoring by throwing themselves to the floor to get in the way of the ball. There are various techniques athletes use to throw the ball, and it has been found that using various throwing techniques can be more effective than continuously using one (Campos *et al.,* 2021).

Goalball is kinaesthetically demanding due to the fact all athletes have varying levels of VI. Ear-hand coordination is one element of this and is important for athletes to gain spatial information. The skin of the hand acts as the boundary between the player and the game space, whilst the ear canal detects ball speed and thrower positioning. This enables the athlete to read the game and respond to the situation, enabling them to throw themselves in front of the ball in defending situations (Gomes-da-Silva, Almeida and Anterio, 2015).

To participate in Goalball at an elite level and to ensure the playing levels are fair, athletes must go through a classification process which assesses the athlete's visual acuity and field (Powis and Macbeth, 2020). To play Goalball internationally, athletes must classify as B1, B2 or B3. These are the levels of VI recognised for recreational competitions and International or Paralympic training pathways. The most severely impaired players are B1 (Powis and Macbeth, 2020). B1 players have an inability to recognise shapes and no light perception, however some can perceive some movement. B2 players have limited vision in either how far or wide they can see. This means players could count their fingers or be able to recognise/read something at a short distance. B2 includes players whose visual field is significantly reduced even if visual acuity is higher. B3 players have limited visual acuity and/or limited visual field. This is the highest category used for international Goalball (British Blind Sport, 2024). To ensure a level playing field, black out eye masks are worn to ensure fairness (Rich *et al*., 2022).

Six players make up a Goalball team with three competing on the pitch on each team at a time (Link and Weber, 2018). Players are positioned at either centre, left wing or right wing which ensures players understand their roughly allocated playing area on the pitch. Players must stay in their own halves and matches are split into two 12-minute halves (Floyd and Mowling, 2019). Goals are situated at either end of the pitch; they are the width of the pitch and are 1.3 metres high. The pitches are 9 metres wide and 18 metres in length (Floyd and Mowling, 2019). The pitch is sectioned into six even areas which are 3 metres lengthways and are the width of the pitch (9 metres). The middle two areas are referred to as the neutral zones, whilst the areas just in front of the Goals are the team area and beyond that is the teams landing zones. The court is marked through raised lines which make the pitch tactile so athletes can feel along the lines to find their boundaries/location. Gomes-da-Silva, Almeida and Antero (2015) describe Goalball as a 'tactile auditory game' and reports tactile perception as a key strategy of Goalball showing the importance of tactile lines. There are six hash marks located on the pitch to assist athletes in orientating themselves; this includes three at the front, one on either side and one on the goal line. Players are only able to throw the ball underarm but can move anywhere in their area to do this. Kicking and overhead throws are restricted.

If a game results in a draw in competitive circumstances, matches go to overtime which consists of two three-minute halves or until a goal is scored. If the result is still equal following this overtime period, extra throws occur; the Goalball equivalent of a penalty shootout (Webborn, 2013). In Goalball, the 1.25-kilogram ball has bells inside so athletes can use their vestibular senses to understand where the ball is and where it is travelling to. To ensure athletes can hear the ball, Goalball is played in a silent arena. Players are permitted to communicate via tapping the floor, snapping or making noises (Floyd and Mowling, 2019)

There are two ten second timers which begin when the defending player makes contact with the ball up to when the ball is thrown. If the team takes longer than the ten seconds, a penalty is awarded. Penalty throws are given when athletes or coaches do something not permitted in the rules. Penalty throws are 1 v 1. To conduct this research, the Goalball UK performance pathway was used. This can be seen in Figure 1. This categorises athletes by playing level. In this research, High-Performance, Talent and Academy athletes will be used.

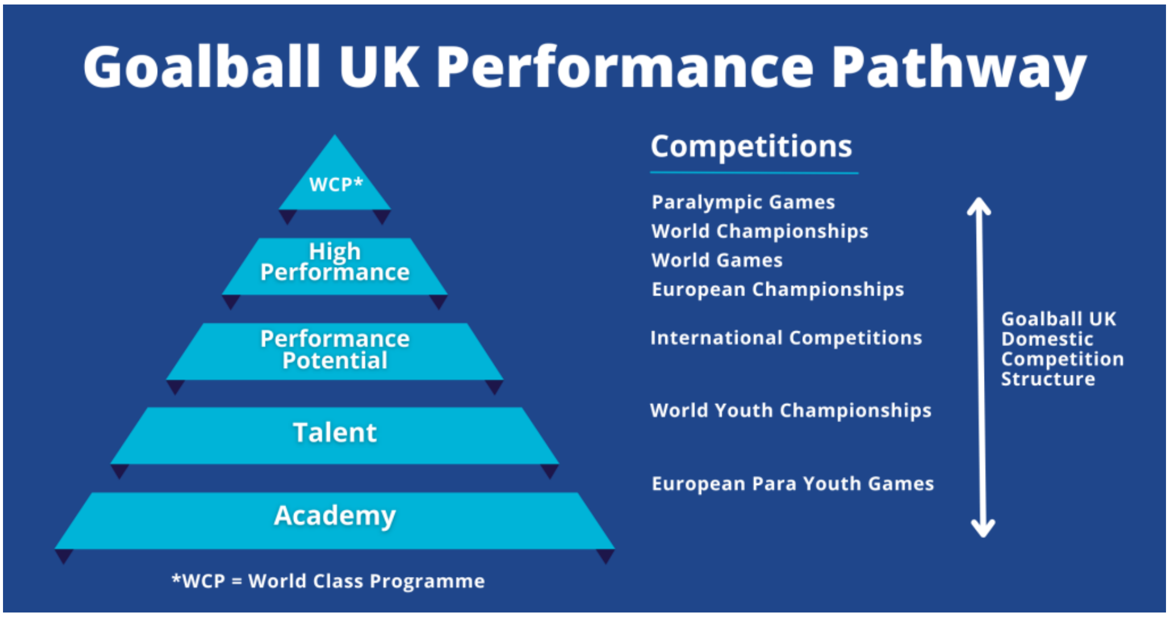

Figure 1: Goalball UK Performance Pathway (Goalball UK, 2024)

1.2 The Research Problem

Performance in Goalball is likely underpinned by several physical, technical, tactical, psychological and social characteristics. However, the research in this area is limited and therefore understanding the physical and psychological (i.e., cognitive) demands of Goalball to a greater extent may in turn enhance performance in Goalball. There is limited research regarding Goalball and the characteristics which have the greatest difference on physical performance and their relevance to Goalball and if so, which characteristics are different between levels of performance despite its emergence as the most common VI team sport. Due to this, Goalball performance needs to be better understood by the key characteristics which cause a difference on performance, to enhance success rates in competition and which characteristics may differentiate between performance levels of Goalball. This may also help coaches with performance training programmes to ensure athletes are being trained correctly, enhancing the characteristics which will have the largest difference on performance. The Goalball population is challenging to reach due to the fact athletes are often not full-time within their sport. Often testing does not go to plan due to the complex needs of athletes which can cause many limitations to research. Information can be collected based upon different key characteristics which heavily influence performance. These characteristics have been shown to be efficient in similar sports and have also been decided on impressions of Goalball UK practitioners. In this novel thesis, we examine the physical and cognitive characteristics which have a difference on sporting performance in Goalball and whether the significant characteristics differ between levels of performance in Goalball.

2.0 Literature Review

Research has suggested that Goalball performance is likely determined by physical characteristics including Sprint performance, Shoulder strength, Lower limb Power, Maximal strength, Core stability, Muscle endurance and Aerobic capacity (Alves *et al.,* 2018; Goulart-Siqueira *et al*., 2018; Goksen and Ince, 2024; Jorgic *et al*., 2019; Mahrokh Moghadam, Zarei and Mohammadi, 2021). Goalball performance has also been identified to be affected by psychological characteristics including cognition (Santos *et al*., 2018). These characteristics will all be researched in this paper and the difference they have on Goalball performance. Throughout this thesis each characteristics importance will be explained as well as its relevance and effect on performance.

2.1 Importance of physical characteristics

For Goalball players to be proficient to a high level, it is essential for their training programmes to be backed up by research looking at physical excellence within the sport and the essential characteristics which must be attained. It is important for coaches to have elevated volumes of knowledge regarding the physical aspects of Goalball so that the information can be used to inform long and short-term planning of athlete training programmes. Originally, physical fitness was described as the attributes in which a person has in relation to their ability to perform tasks (Caspersen, Powell and Christenson*,* 1985). Corbin, Pangrazi and Franks, (2000) found that agility; balance, coordination, power, speed, cardiovascular endurance, muscular endurance, muscle strength and reaction time are all physical characteristics within sport. It has been reported that persons with VI tend not to utilise movement and exploration skills (Demir and Sen, 2009). Atan and Avca, (2015) highlighted that visual loss is not directly associated with loss of motor or physical function, however can affect developmental function due to insufficient physical activity, environmental manipulation as well as limited experience within the environment. They point out that the motor development delay is not in those who have subsequently lost their sight but is however in those who have been VI since birth.

Roztorhui *et al.,* (2019) showed those with a severe VI to have significant differences in speed development, flexibility and coordination when compared with those with moderate sight impairments. The aim of their research was to determine the influence of adaptive sports training on the physical preparedness of athletes. They completed a pedagogical experiment with theoretical analysis and pedagogical observation. Testing was completed on 34 severe and moderately VI persons. Participants took part in various strength, speed, coordination, endurance and flexibility tests for a total of 40 hours. They identified that the level of VI influences indicators of physical preparedness. They found a significant improvement in all test indicators for everyone with VI, implying adaptive sports training has a positive difference on physical preparedness. This indicates a relationship between level of VI and impact of adaptive sports training on physical preparedness. This research can be applied to training as it was completed over 40 hours across training sessions rather than lab-based testing. VI persons may suffer from joint, nerve and muscle coordination issues as well as poor physical and psychological development because of insufficient physical activity (Keskin, 2008).

Colak *et al.,* (2004) conducted a study which looked at the effect of Goalball on measurements of motor fitness. 103 male 13–15-year-olds took part all with varying degrees of VI. Participants took part in motor assessments such as balance tests, handgrip, flexibility, vertical jumps and isokinetic assessments. Significant differences were found between those who took part in Goalball and those who did not. Those who did participate in Goalball were found to have superior motor fitness components when compared with the VI subjects who did not participate in Goalball. This shows Goalball can be an effective way of increasing motor skills in VI persons. Similarly, Krzak, Slezynska and Slezynksi (2015) looked across a 4-year period at motor skills in fifteen 16–18-year-old VI and blind Goalball players and ten VI students who have never participated in Goalball but have completed physical education activities. They found substantial progress in motor skills such as physical fitness, spatial orientations and sound localization in Goalball players. They showed Goalball as a worthy sport to be socially and personally beneficial for VI persons. This study helped enhance the need for the current study due to the fact motor skills gained from Goalball have been noted to benefit VI persons. However, motor skills have not been compared between levels of Goalball players but across Goalball and non-Goalball players.

It has been found that health related physical fitness can be improved through Goalball with improvements found in muscular strength, cardiorespiratory endurance and muscular endurance (Karakaya, Aki and Ergun, 2009). Covering all characteristics of Goalball are essential when training athletes seeing as when compared with fully sighted people; VI people tend to present poor flexibility, postural control, poor neuro-psycho-motor and perceptual developments, low cardiovascular and muscular endurance (Zhikai, Zizhao and Junsheng, 2023).

To help VI athletes prepare for competition, Winnick and Short (1999) developed the Brockport Physical Fitness Test (BPFT) which is a test battery which looks at aerobic capacity, body composition and musculoskeletal functioning. However, the literature backing up this manual was specific to the general population with disabilities rather than VI Goalball athletes. Therefore, this test cannot be generalised to the Goalball population and enhances the need for development of standard testing procedures for Goalball athletes. A scoping review by Petrigna *et al.,* (2020) found amongst the research regarding Goalball, there is not a standardized test battery to evaluate Goalball athletes and future research is needed to develop the physical characteristics of Goalball in athletes. They used a total of 7 papers across 222 participants. It was suggested that the BPFT could be adopted and standardized to the characteristics of Goalball as a key operating procedure in Goalball as it was the only test battery which also evaluated general well-being of athletes. However, this test still holds limitations which have already been noted regarding generalizability. Therefore, it is essential that the main physical characteristics of Goalball are researched so a standardized operating procedure can be worked towards.

2.2 Anthropometric measurements

A review by Lorenz *et al.,* (2013) found several variables to have been investigated when defining an elite athlete across a variety of sports, in particular, physical performance. Robbins, (2010) investigated American football and found it requires both physical and cognitive skills to be successful with 8 physical performance tests which sustain elite from non-elite athletes. When compared with the standard anthropometric characteristics such as height and weight which coaches often use to categorize athletes, it was found that the physical tests are more relevant to sporting performance with anthropometric measures being less important. Overall, the review found that across multiple sports, physical characteristics can differentiate between elite and non-elite athletes. It is important however to recall that physical characteristics alone cannot define success. Likewise, Bakir and Aydogan (2011) found that anthropometric characteristics such as height and weight had no difference on the reaction time of Goalball players and a study by Temur *et al.,* (2014) also found these measures not to affect physical capabilities. Molik *et al.,* (2015) found that arm length, body length, and arm span has no significant relationship with performance and therefore coaches should not consider such differences when selecting elite athletes.

Alternatively, Romanov *et al.,* (2017) found that when defining morphological profiles of Goalball athletes, body height was important and was also backed up by indicators of nutritional status such as body mass. Interestingly, a correlation analysis took place, and a connection was established between the ratio of the hips and waist circumference and achieved team placement. Romanov *et al.,* (2017) found that this highlighted the importance of distribution of adipose tissue in defining the morphological profile of a Goalball player.

Additionally, a systematic review by Utvic *et al.,* (2019) looked at the anthropometric profiles of Goalball athletes. They initially collected 108 articles and resulted with 14 articles. They found in Goalball; body height was a crucial factor in contributing to greater arm span. They found this increased athlete space coverage in match scenarios as well as contributing to the percentage of muscle tissue in relation to muscle strength. They also found that often Goalball players have body mass problems with an excess of fatty tissue due to poor nourishment. This could cause negative anaerobic and motored abilities. They did however find that body composition did not influence athletic tournament performance and is likely that technique and motor success had a larger difference on athletic performance than body composition.

2.3 Sprint performance

Sprint performance has been identified as a key characteristic within Goalball aiding the attack phase. Sprint acceleration is the rate of change in running velocity. Positive instantaneous acceleration over time implies sprint velocity increase (Petrakos, Morin and Egan, 2016). In Goalball, players build up speed across 6 metres from the goal line to the high ball line. Therefore, athletes primarily go through the drive phase of acceleration before decelerating. Within this phase, horizontal force is a key component, and this encourages the activation of the hip extensor muscles prior to ground contact (Morin *et al.*, 2015). Hip and knee extensors as well as concentric force development are the main influencers of acceleration. This is due to the fact they allow the activation of muscles to contract and relax to facilitate the movement and allow for the forwards propulsion through extensor torque by rapidly accelerating the body up and tilting the pelvis (Neumann, 2010). Concentric force development allows for explosive contraction in the early acceleration stages (Maffiuletti *et al.,* 2016). Horizontal force relates to Newtons second law of F=ma which looks at bodily forces being exerted upon the ground causing momentum to be created in the direction of the force, resulting in acceleration (Watkins, 2014). It was found that Goalball represents a high intensity physical demand of 85%-100% of maximal heart rate and that due to the high intensity of these movements, anaerobic efforts using the alactic metabolism are most important in the sport (Theophilos *et al*., 2005).

Jorgic *et al.,* (2019) investigated the influence of motor abilities on throwing velocity amongst 12 national and international Goalball players measuring sprint performance over 5 and 10 metres, standing long jump and medicine ball throws. They identified that it is necessary to improve explosive strength and sprint performance to aid the ability of a rapid transition from defence to attack, as well as aiding ball throwing velocity significantly. It was found that all variables were statistically significantly connected, and all had an influence on throwing velocity. This shows a great importance to develop both lower and upper body explosive power. More specifically, it was found that those with better sprint performance participated in more efficient counter attacks seeing as defensive players had not assumed position, therefore opportunity to score was increased. It was found that the 5-metre sprint was an important indicator of speed ability amongst Goalball players and the 10-metre sprint was a standard test of sprint ability amongst athletes. Especially in the later phases of play, the players which are physically fitter hold an advantage over the opposition. Further to this, Goalball implies a 10 second rule where from the moment the team touches the ball, they must then release the ball within 10 seconds. This shows the need for explosive reactions and therefore players must be as fit as possible to aid this anaerobic transition. The greatest velocity and speed occur in the first few steps and players have 6 metres as previously mentioned to accelerate and decelerate which shows explosive strength and acceleration ability to be critical. This research paper highlights the need for further research into the correlation between motor skills to effectively aid performance between levels of performance. As well as this, investigating other areas which can affect the variables identified in this paper are important such as muscle strength and endurance. The current research paper will investigate differences between skills and which best aid Goalball performance.

Another study by Atan and Avca (2015) looked at the Goalball performances of 38 VI students. They assigned 19 students to a control group and the remaining 19 participated in Goalball where performance measurements were recorded over a 3-month period, pre-test and post-test. Athletes participated in a 10m sprint. No statistical difference was found between the two groups following the pre-test sprint however significantly shorter sprint times were established in the exercise group following 3-months of training. In the control group, values remained the same. This study showed that those participating in Goalball had a positive improvement to their fitness and speed compared to those who did not and therefore they encouraged VI persons to participate in sports. Although this paper is beneficial in the fact it highlights Goalball to have a positive effect on sprint performance, further research is required to look at the effects of sprint performance in Goalball between levels of performance. The current research study will aid in identifying this. Similarly, Sahin (2007) completed a 2-month study investigating the influence of regular exercise training on physical and physiological parameters of children aged 12-14. There were no statistically significant differences between the control and experimental group in relation to sprint time pre-test. However, a decrease in sprint time was observed following two months of exercise.

2.4 Lower limb Power

Power has been identified as an important characteristic in determining success in sport. Rate of strength development, stretch shortening cycle, speed strength and intra/inter muscular coordination are all important characteristics which contribute to muscle power (Gamble, 2013). Power has been simply defined as "the product of force (mass multiplied by acceleration) divided by velocity (distance/time)" (Santos and Franchini, 2021, p.133). There is a positive linear relationship between muscle power and maximal strength. Therefore, for athletes to reach maximal power they must first reach higher levels of muscle strength (Cormie, McGuigan and Newton, 2011).

Lee, Lee and Park, (2020) Compared levels of peak power between male VI Goalball (n=5) and Judo (n=4) players in both the upper and lower limbs. They found that lower limb body power in Goalball athletes showed a higher peak power value and mean power value, but no other significant differences were found. They identified Goalball to be a high intensity and fast movement game which means higher energy supply rate by the Adenosine Triphosphate Phosphocreatine system than the glycolytic system during maximal anaerobic exercise. They found the rate of fatigue to be significantly higher in the lower limb of Goalball athletes when compared with Judo athletes. This implies the importance of improving lower body power in Goalball to reduce the rate of fatigue throughout the game and ensure the high intensity is maintained. However, a lower rate of fatigue was found in the upper limb of VI Goalball athletes when compared with VI Judo players. This suggests higher rates of anaerobic power in the upper body of Goalball players which can aid performance as athletes will not fatigue as quickly. One limitation to this research is the lack of correlation between lower body power and performance parameters such as aerobic performance and muscular endurance which can affect fatigue levels. The current research paper will identify the performance parameters which can affect Goalball performance which can then be used in future research to identify which factors need to be improved to reduce fatigue levels.

One way in which muscular power can be tested is through jump testing. Vertical jumping involves complex motor coordination and is identified as a fundamental movement skill and can be used to evaluate lower limb strength and power (Gallahue, 2002). Liebermann and Katz, (2003) identified the vertical jump to be highly valid and reliable in testing muscular power in comparison to other tests such as a leg press, 20m sprint or knee extension in isokinetic device. An extremely similar test used to test muscular power is the sergeant jump test. This evaluates athlete's lower leg power and can be correlated with athlete's explosive muscle strength (Sargent 1921). This test however is old in literature and reviews would need to look at the statistics in the modern-day athlete to confirm efficacy. When performing either jump tests, Petrigna *et al.*, (2019) has provided standard operating procedures which should be used to increase test-retest reliability.

Goulart-Siqueira *et al.*, (2018) investigated the relationships of different physical tests relating to performance in 11 Brazilian elite Goalball players. Their results highlighted the suitability of the counter movement jump (CMJ) in monitoring Goalball athletes. They found it to be the only test which had a strong correlation to body composition, maximal handgrip isometric force and the highest correlation was noted with throwing velocity which has been identified as another key characteristic of Goalball. They therefore labelled the CMJ as a valuable monitoring tool in Goalball. Their CMJ results were better than those reported by Colak *et al.*, (2004) who looked at a sample of sub-elite Goalball players. This identifies the improvement in power through the performance levels, with elite players performing better than sub-elite players. This shows power to be a desirable attribute in Goalball which can be seen in throwing and defensive actions where contribution of energy is provided by anaerobic alactic metabolism (Alves *et al.,* 2018). They concluded that the CMJ was a valid material for the monitoring of Goalball players regularly to test lower limb power.

Munoz-Jimenez *et al.,* (2021) looked at competitive Goalball performance across genders. They found muscle power to be the most relevant distinguishing factor between male and female competition in defensive and attacking actions. They suggested athletes should be prepared to maintain their muscle power performance level throughout key moments of the match. They noted that men were more powerful in their offensive actions whereas women were more tactically organised and therefore did not need to perform such powerful movements. This can suggest that the more tactically efficient athletes are, the less powerful athletes need to be to be successful in competition.

2.5 Shoulder strength

One critical fitness parameter in sporting performance and daily life is muscle strength. Upper body muscle strength is one of the characteristics identified in being essential in Goalball, with shoulder strength playing a prevalent part in throwing ability. Muscle strength can have significant effects on throwing ability as well as the ability to prevent injury (Carter *et al*., 2007). Muscle strength is defined by the International Classification of Functioning, Disability and Health, (2001) as the voluntary maximal resultant output in which muscles can bear on environment under a specific set of test conditions.

The rotator cuff, latissimus dorsi, deltoid, biceps, teres major and pectoralis major muscles are responsible for shoulder stabilization. Inman *et al.,* (1944) first stated that the coactivation force of shoulder dynamic stabilizers provide joint stability. If forces are not equalized, joint mechanics and stability may be compromised (Salles *et al.,* 2015). It is essential to have excellent joint stability and can be improved via physical training. Training must be directed at attaining proportional strength surrounding the joint to achieve joint stability (Salles *et al*., 2015).

The main goal of Goalball is to get the ball to the goal. Rotary throwing and straight throwing are the two main techniques used in Goalball. The most traditional type of throw in Goalball is the straight throw. This is an underarm throw which resembles the motions of a bowling throw. The rotational throw looks at a rotating movement like the motion of a discus throw (Bowerman *et al.,* 2011). Although literature lacks, the rotational throw provides more acceleration and a harder shot (Makaraci *et al*., 2022). Goalball players who prefer rotational throws have better internal rotation joint position sense and agility (Makaraci *et al*., 2022). Rotational throwing has a high goal rate, however is the more difficult of the two techniques, therefore requiring more biomechanics.

Coaches must be able to recognise and analyse which type of throw is best suited to their athletes. It is important that they can identify the phases of movement to recognise technique errors / faults and correct them. Identifying athlete's stronger areas of the muscle group of the shoulder will also increase performance parameters as they will be able to recognise which area the athlete is stronger in.

Gender plays a large factor in muscular strength. Sinaki *et al.,* (2001) found men to have more muscular strength than women both in daily living and in sport. They conducted a study looking at gender and age differences in muscular strength. They found reduced muscle strength in women across all ages from 20 to 89. Their study showed physiologic reduction of muscle strength which commenced early in life across female subjects which in turn stopped the improvement of muscular strength later in life. They encouraged muscle strengthening at all ages to restrict the deterioration of muscle strength. Balci *et al.,* (2021) recognised that to their knowledge, there is no literature comparing muscle strength in female and male athletes with disabilities. They found in sighted individuals that isometric muscle strength was higher in male athletes than in female athletes except in values of leg flexion and elbow extension. This highlights the need for further research comparing muscle strength between male and female athletes with disabilities.

Andrade *et al*., (2016) investigated the relationship between muscular strength and throwing performance in Goalball, looking at the influence of muscle fatigue from simulated game activities on shoulder rotational isokinetic muscle strength, balance and throwing performance. 10 elite handball players participated in this study. Rotator peak torque internally and externally was measured pretesting and post testing. It was found that following simulated game activity, peak torque of internal and external shoulder rotators was reduced. It was however found that the fatigue from exercise did not affect throwing velocity. Isokinetic variables were found to have positive correlations with ball velocity. The simulated game activity had more of an effect on the internal shoulder rotators than the external shoulder rotators which could suggest a muscular imbalance within the shoulder. This suggests the shoulder rotators should be further investigated within Goalball to see if muscle imbalances can have a further effect on throwing velocity.

Zapartidis *et al.,* (2007) investigated the relationship between shoulder strength and ball velocity / accuracy within handball through simulated game activities. 16 female athletes participated in this study. Ball velocity remained stable in this test whilst throwing effectiveness was decreased as accuracy decreased with time. They found rotational strength of the shoulder did not have a significant effect on accuracy whereas time to throw did. This suggests that the shoulder strength of athletes does not affect their ability to throw the ball or their accuracy. As a matter of fact, the study looks at time constraints as a significant factor in the effectiveness of throwing, suggesting technique is reduced when athletes are placed under time pressure rather than a shoulder weakness causing inaccuracies. As Goalball players only have 10 seconds to release the ball after receiving it, this study could be seen as relative to Goalball. This study does however investigate rotational shoulder strength. Other segments of the shoulder may have an alternative effect on results. Further research is needed to investigate the impact of muscular strength and fatigue levels on ball velocity. The methods used in the current study will assess shoulder strength at different points and the ability to transfer force across the shoulder girdle.

Chelly, Hermassi and Shephard (2010) also looked at the relationships of upper limb strength and power in Handball. 14 male handball athletes participated in a one repetition max bench press and pullover exercises. They looked at throwing performance to be key in game success with muscle strength being a direct correlation. They found that both upper and lower limb strength had a direct correlation with throwing performance. When throwing at high velocity's it was found the critical component to be the ability to transfer force from the lower body to the upper body to aid the force then transferred on to the throw (Morriss and Bartlett, 1996). When results were looked at relative to body mass and limb muscle volume, the relationship to throwing velocity then became non-significant. This suggested the importance of the contribution of body mass and muscle volume to enhance throwing performance. They suggested the introduction of both upper and lower limb strengthening to aid throwing ability. Similarly, it was found in another paper that the strength differences between elite and amateur handball players disappear if results are relative to body mass (Gorostiaga *et al*., 2005). They compared physical characteristics in two handball teams, 15 elite players and 15 amateur athletes participated. They identified that more muscular players have an advantage in handball and that the differences in fat free mass can explain the differences in results in terms of absolute maximal strength. This shows body mass can have a large effect on throwing performance and hence solely just upper limb strength cannot always be relied on.

Goksen and Ince (2024) conducted a study with 15 sub-elite female and male Goalball players looking at throwing technique of according to VI and sensory functions. The flexor muscles were found to be more active during spin shots with eyes open whilst the extensor muscles were found to be more active during the spin throw with eyes closed. They found no differences in throwing velocity between different throwing techniques or VI. They observed that throwing performance is greatly related to upper extremity flexor muscle strength rather than VI. They found the spin throw was not advantageous for ball velocity of sub-elite players despite its precedence as an advantageous movement biomechanically for elite players. It was recognised that internal shoulder rotation is used more in daily activities of living, and it was found that internal rotation joint position of the shoulder was more successful in the low VI group when throwing. The shoulders proprioceptive joint senses affect throwing performance due to the flow of information from the skin, muscles, joints, tendons and tissues during movement patterns. In the proprioceptive process, visual communication provides the most important data. In VI persons, it is assumed other perceptions develop more than in sighted persons however few studies are available which back up this information. To further support this study, future research including the current study can investigate throwing performance on a larger scale and across varying levels of performance.

To reduce the chances of a muscular imbalance of the internal/external rotator cuffs, a large emphasis is placed on the choice of exercise selection for the larger muscle groups. It is therefore important to ensure exercise selection looks at strengthening all muscles across both the internal and external rotators (Kolber *et al.,* 2010). Due to the excessive use of the shoulder muscles in Goalball due to repetitive throws, they are put more at risk of injury. Kolber *et al.,* (2010) completed a review which compared external shoulder rotators to internal shoulder rotators in athletes which participate in resistance training. They found that deltoid to external rotators and upper to lower trapezius that muscle imbalances were identified exceeding that of the general population. Incorporating certain flexibility exercises focused on the posterior shoulder tissue can improve posterior shoulder restrictions and internal rotation mobility. Overall, this would provide players with balanced joint mobility and reduce injury across the shoulder joint. Fredriksen, Cools and Myklebust (2020) investigated shoulder strengthening exercises through a modified Delphi study which will not only reduce the risk of injury but will in turn improve performance. Twenty-eight exercises were rated, and efficacy and adherence were found in only two exercises which can strengthen external rotator shoulder strength. An external shoulder rotation at 90 degrees of abduction with trunk rotation in a push up position and shoulder extension in a bent over squat position were both found to be efficient in strengthening the external rotators of the shoulder. This can be related to Goalball as rotational shoulder strength can be identified as a key characteristic of athletic performance.

2.6 Maximal strength

A wide range of people complete maximal strength training and numerous health benefits have been documented because of it (Kraemer and Ratamess, 2004). An improvement in strength not only improves daily living and health but can also enhance performance in areas such as speed and power due to the increase in muscle recruitment (Fyfe, Hamilton and Daly, 2022). Maximal Strength is the maximal voluntary force a specific muscle or group of muscles can exert under specific conditions and in human performance it is seen as an essential component (Baechle and Earle, 2008).

Sporting movements typically consist of some plyometric characteristics such as sprints, changes of direction and exercises where one repetition maximums are completed such as a squat, deadlifts and bench press where high levels of force production are required (Fry, 2004). Maximal strength works through the ability of recruiting and engaging all motor units of the muscles to generate maximal force against an external resistance and will eventually load to a greater force production (Suchomel *et al.,* 2018). Therefore, to generate enough force to complete actions which require maximal strength, muscle fibres must be activated to aid the generation of maximal force. The stretch shortening cycle categorizes the muscle fibres by fast

(<250milliseconds) which includes movements such as sprinting and bounding or slow (>250 milliseconds) which includes changes of directions and countermovement jumps (Hennessy and Kilty, 2001; Turner and Jeffreys, 2010).

Specific morphological characteristics such as tendon properties, architecture and muscle fibre type are key in dictating maximal strength qualities. Neural characteristics also play their part with motor-unit recruitment, synchronization, intermuscular coordination and firing frequency also affecting maximal strength qualities (Cormie, McGuigan and Newton, 2011). These adaptions influenced by maximal strength training either have a positive or negative affect on athletic performance. To maintain a positive transfer, athletes must continue with training program development which target the appropriate quality areas stated above to improve the desired movement (Verkhoshansky and Verkhoshansky, 2011).

Suchomel, Nimphius and Stone (2016) reviewed previous literature which examined the importance of muscular strength on performance. They found muscular strength to be an essential determinant of strength-power relationships and endurance performances. It was found that stronger athletes out-perform weaker athletes in both strength-power and endurance sports. They found 94% of correlation magnitudes had a moderate/greater relationship with strength and 83% displayed greater/large relationships with strength. Studies have displayed that stronger athletes perform better in activities such as cycling and sprint time (Stone *et al*., 2004). In hand ball it was found that stronger athletes had a greater standing and 3-step running velocity which can be familiarised to Goalball in terms of the stand and short acceleration to release the ball (Gorostiaga *et al*., 2005).

Stone *et al.,* (2003) suggested that power performance is highly affected by maximal strength. Those athletes which are stronger have a potential for greater development of power (Cormie, McGuigan and Newton, 2010). Research has proven the effectiveness of the isometric mid-thigh pull (IMTP) in testing maximal strength. Strong correlations have been found relating the IMTP to athletic performance aspects such as peak power, sprinting, countermovement jumps and shot-put power (Kawamori *et al*., 2006; Stone *et al.,* 2003; Thomas *et al*., 2015).

Beattie *et al.,* (2017) conducted a study which investigated the relationship between the IMTP and reactive power performance (drop jump reactive strength index). 45 college athletes from various sports participated in a IMTP to measure peak force and a drop jump reactive strength index at a range of 0.3-0.6m box heights. They found that stronger athletes performed significantly better in terms of reactive power performance than weaker athletes. Weaker athletes declined in performance in terms of RSI as eccentric stretch loads increased (0.3-0.6m box height). The stronger athletes on the other hand maintained reactive strength abilities. This implies that there is a strong relationship between maximal strength and reactive power performance in sporting performance and improving the neuromuscular qualities are essential for elite sporting performance.

On the other hand, Healy *et al.,* (2019) investigated the influence of maximum strength indicators on sprint performance. 14 male and 14 female sprinters participated in this study. 40m sprints were completed as well as an IMTP, drop jump and vertical hops. They found that the IMTP was not significant in relation to sprint performance measures, but the male sprinters performed better than the female athletes in all measures apart from hopping. In comparison to other studies, it was found the IMTP is significant in relation to sprint performance measures in short sprint distances >20m but not those which exceed 40m (Thomas *et al.,* 2015; Wang *et al.,* 2016). This identifies the importance of maximal strength in Goalball due to the reactive movements from defence to attack and vice versa in terms of throwing, sprinting and transitions in play. The evidence suggests stronger athletes perform better in comparison to their weaker counterparts.

2.7 Core stability

To maximise efficient athletic performance, core stability is an essential component. The general definition of core stability is the "ability to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities" (Kibler, Press and Sciascia, 2006, p.190). Almost all kinetic chains and sport activities are controlled centrally by core stability. Core strength control, balance and motion maximises kinetic chains of lower and upper extremity function (Kibler, Press and Sciascia, 2006). They identified the core as the base of stability and the 'engine' of force generation. The thoracolumbar fascia structure connects the lower limb via the gluteus maximus to the upper limbs via the latissimus dorsi. This is important in Goalball as it allows the core to be included in kinetic chain activities such as throwing (Kibler, Press and Sciascia, 2006). Studies have investigated the effect of core stability training on athletic motor function in a variety of fields and found this type of training to have a positive effect on performance (Hibbs *et al.*, 2008).

The stability of the core plays an essential role in effective biomechanical performance and is an essential component in the performance and maximal efficiency of athletes and prevention of sports injury. Core stability is vital for all upper and lower limb movements. The trunk muscles are initiated before the limb muscles to stabilise the spine as a structure for functional movements (Hodges and Richardson, 1997). The trunk area is essential as it acts as a connection to perform sports through the transfer of forces between the lower limb to the upper limb (Samson, 2005).

A study investigated the effect of eight weeks of core stability training on functional movement screening in elite Goalball players. 26 elite Goalball players participated and were split into an experimental and control group. Eight weeks of core stability training using a Swiss ball was completed. The results from this study showed core stability training to improve the score of the functional movement screening test in Goalball athletes (Mahrokh Moghadam, Zarei and Mohammadi, 2021). They recommended the use of core stability training in being effective in improving athletic performance. Core stability training is therefore seen as a key component in Goalball due to the results showing core stability having a positive effect on motor function of Goalball players.

For movements in all directions to be controlled, deep stabilizer activation of the multifidus and transverse abdominis are essential. Local and global muscles of the trunk have a synergistic relation in the stability system. If the lumbar paraspinal muscles are weak, the ability to transfer deep stabilization to the hip/pelvis area becomes noticeable which in turn reduces the condition of the hip extensors. Lumbar stabilization exercises target mainly local muscles, some evidence suggests high load lumbar stabilization exercises such as glute bridges could recruit global and local muscles enhancing core stability (Okubo *et al.,* 2010).

Players movement patterns are affected due to postural weakness and vision loss (Soares *et al.,* 2011). A reduction in core stability can reduce effectiveness of correct movement patterns (Zazulak *et al*., 2007). Movement pattern changes cause compensatory patterns of movement, muscle strain, overwork and ultimately injury (O'Connor *et al*., 2011). Defects in stability muscles reduce muscle strength responsible for the kinetic chain, reduction in ability to maintain balance, increasing reaction time, weakness in muscles and centre of gravity within support surfaces (Zazulak *et al*., 2007).

Core stability training has been found to have a positive effect on throwing velocity in Goalball players (Mahrokh Moghadam, Zarei and Mohammadi, 2018). Further research has found rotating throws allow for higher ball velocity (Bowerman *et al.,* 2011). In the rotational movement, postural control and core strength both play a significant role and are essential for optimal performance. It was identified that in terms of Goalball, higher core stability allows a higher precision rate and throwing velocity, increasing attack performance (Bataller-Cervero *et al*., 2022).

2.8 Muscular endurance

VI persons tend to show low muscular endurance (Skaggs and Hopper, 1996). Goalball can have a positive difference on health-related characteristics such as muscular endurance (Colak *et al.,* 2004). Muscular Endurance is the ability for muscles to be able to maintain a contraction or perform repeated contractions against a load for an extended period (Kell, Bell and Quinney, 2001). Increasing muscular endurance can have a positive difference on musculoskeletal metabolism and the cardiovascular system and are associated with reduced injury, mortality, increased ability to complete daily living activities, functional capability and reduced incidence of falling (Kell, Bell and Quinney, 2001).

Research has suggested to support the musculature of the core, that muscular endurance is more important than muscular strength and therefore testing should focus on endurance (Knudson, 1999). Muscular endurance is key in Goalball as players must be able to maintain high performance levels throughout the duration of the game. To increase muscular endurance, athletes should incorporate aerobic exercises such as cycling or swimming. To be Goalball specific, activities such as repeated dives and quick throws can improve muscular endurance.

Zuo *et al.,* (2022) compared the effect of 6 weeks of resistance training on muscle endurance and performance. They identified that resistance training with high repetitions and lighter loads can enhance endurance. When six weeks of traditional resistance training was compared with functional resistance training across 29 untrained young males, no statistically significant differences were found which suggested either form of training were suitable to improve resistance training.

Similarly to this, another study investigated 32 untrained men who participated in an 8-week progressive resistance training program which investigated strength endurance. Participants were separated into three groups, low resistance, moderate resistance and high resistance. It was identified between high, moderate and low repetition groups in resistance training that those with higher repetitions showed a greater rate of submaximal prolonged contractions whilst the low to moderate repetitions induced greater hypertrophic effects in comparison to the high repetition group (Campos *et al.,* 2002). It suggests different forms of resistance training can induce muscle capillarization and mitochondrial adaption. This suggests that resistance training can have a positive effect on muscular endurance which in turn will benefit performance.

Contrary to this, a systematic review by Xiao *et al*., (2021) investigated the effects of functional training on physical fitness. Their results suggested that functional training could cause an increase in physical fitness components such as muscular endurance, however functional training only had a moderate effect on muscular endurance. They suggested this was because in the studies recorded, the sit up test used looked at measuring rectus abdominal endurance rather than deep core musculature and could explain the lack of significance between intervention and non-intervention group. This implies that endurance training must be specific to the muscle area of importance to see an improvement. To avoid errors in research by measuring endurance of the wrong muscle groups, the current study will explore muscle endurance by isolating muscle groups within the body.

Another way of improving endurance in athletes is through isometric training. Ribeiro-Alvares *et al*., (2018) found that isometric training improved isometric hamstring peak torque and increased fascicle length. They compared twenty active young adults into a training group and a control group, and the training group participated in a 4-week Nordic hamstring exercise program twice a week. Not only does this reduce likelihood of injury but also increases the strength of muscles and therefore the strain they can withhold. In Goalball, practitioners may be able to identify weaker muscle areas and can use isometric training to target the weaker zones which will therefore have a positive difference on performance as well as enabling dynamic loading without athletes experiencing any pain (Rio *et al.,* 2015).

2.9 Aerobic capacity

Goalball helps those with VI to improve general fitness and aerobic capacity (Gulick and Malone, 2011). As an athletic task becomes prolonged, the predominate energy source progressively becomes aerobic. This means that more and more fractions of adenosine triphosphate (ATP) are required to fuel the skeletal muscle contractions. This occurs from the oxidation of fatty acids and glucose by the mitochondria (Costill, 1970). Aerobic capacity was defined by Green (1994, p.171) as the "total amount of external work performed during a specific type of exhausting exercise which is of a sufficient duration to incur a near-maximal anaerobic ATP yield, given that this ATP yield exceeds that from oxidative metabolism".

Gulick and Malone (2011) originally compared aerobic fitness in female Goalball athletes in laboratory conditions (bicycle ergometer) in comparison to a field beep test performed on a Goalball court. They found the field beep test to be valid in testing aerobic capacity among female Goalball athletes with a strong correlation (r=0.77) being indicated between the bicycle ergometer and the modified beep test and found aerobic capacity to be low amongst these Paralympic female athletes. In agreement with this, Goulart-Siqueira *et al.,* (2018) also found aerobic capacity to have low values in Goalball athletes when completing the Yo-Yo test. They identified that performance of Goalball athletes in the Yo-Yo test is below levels of other elite athletes, and this suggests that the test is not specific for testing aerobic capacity of Goalball athletes especially as this test can measure both aerobic and anaerobic metabolisms. This can suggest aerobic capacity is not an important feature of Goalball and that further investigations on aerobic tests should be completed to better measure aerobic capacity. The current study will adapt testing to accurately measure aerobic capacity without the limitations of VI interfering with results.

Alves *et al.,* (2018) investigated the comparison between laboratory test parameters and physiological variables obtained during simulated games within Goalball. They investigated 7 elite Goalball players. They found that Goalball has a great effect on the aerobic and anaerobic alactic pathways most and that laboratory testing performed better to game conditions which preached the need of standardization of testing. When compared to the study presented by Gullick and Malone (2011), it was found that a peak VO_2 max was higher from this study, and this could be due to the difference between using a bicycle ergometer and conducting simulated play and the intermittent breaks present during Goalball games. Their results demonstrated that aerobic metabolism was more required during a Goalball game than anaerobic metabolism. Due to the lack of players used in this study, results can be interpreted cautiously and further research with larger sample sizes should be conducted which may provide more reliable results. This suggests that aerobic conditions are seen more frequently in a Goalball environment and dismisses the idea that anaerobic participation is key in Goalball performance. Also, the duration of a Goalball game (12 minutes per half) suggests aerobic capacity is key whilst some determinant movements such as throws, and defence moves can be reliant on alactic metabolism.

On the other hand, Furtado *et al.,* (2016) suggested to measure aerobic capacities the 1-mile run test would be more feasible for VI athletes to complete due to the difficulties sometimes obtained in locomotor tasks and tests such as the Yo-Yo intermittent test where change of directions is required. They identified that a game specific protocol would be more appropriate to measure aerobic capacity in VI persons.

2.10 Importance of Cognitive Characteristics

Cognition can be seen in sport as athlete's concentration, orientation, attention and information control. All of which coaches, athletes and researchers value highly when looking at performance parameters. Cognition is referred to as the "ability to coordinate thoughts and actions and direct it toward obtaining goals. It is needed to overcome local considerations, plan and orchestrate complex sequences of behaviour, and prioritize goals and sub goals" (Miller and Wallis, 2009, p.99). Cognitively, players must be able to maintain concentration and be able to use cues for guidance as well as the use of internal spatial maps (Gomes-da-Silva, Almeida and Anterio, 2015). Therefore, due to the fact visual information is blocked, spatial cognitive ability must be of a high level to determine their own position but also their teammates, opponents, the ball positioning and the ability to attack and block. It has been noted that all movements are learnt through verbalization and the body functions through perceptual motor movement of ontological condition in VI athletes (Amorim *et al.,* 2010). VI athletes must use sound source localization which helps to identify the direction and distance to the sound source (Kolarik *et al.,* 2020). It is therefore essential that athletes are cognitively effective to be physically effective due to their VI.

Due to the loss of sight, spatial cognitive ability is key as VI individuals must rely on touch, smell and hearing when in complex environments. Orientation is the most important skill for VI persons (Chen, 2012). Orientation skills allow VI persons to be able to perform daily living activities such as walking to venues, identifying bathrooms and avoiding falling which are crucial for a sense of independence (Chen, 2012). Chen (2012) conducted a study which looked at improving the orientation of VI athletes in baseball through a 10-week training program. It was found that the experimental group showed a significant improvement in orientation and mobility whilst the control group showed little significant progress. Repetitive training can be seen to make significant improvements in the orientation of VI Goalball athletes.

Another study by Santos *et al.*, (2018) also highlights the importance of orientation in VI athletes. They investigated 39 VI athletes across Judo, Goalball and Football. They identified that good performance in Goalball is dependent on the capacity of spatial orientation. This is important so that players have localization of the playing area, and the auditory requirements needed to locate the ball. They identified that the blindfolds used in competition and training in Goalball enhances the effectiveness of other systems when compared to other sports such as Judo. They also found Judo requires less spatial orientation due to the fact there is no penalisation for leaving the fight area and therefore spatial orientation is of a lower priority in training in comparison to Goalball.

External and internal stimuli appear as separate categories, however a continuous cycle is present in which they affect one another. An internal emotion will be triggered by almost all external events and cause an emotional shift in athletes and therefore change the way they show themselves externally (Wilson, Peper and Schmid, 2006). Due to this, athletes must be coached psychologically to be able to cope with intense changes of emotion to deal with the pressure of competition. If concentration skills have not been mastered, performance will suffer, and this is often the downfall of many athletes.

2.11 Cognition

Wilson, Peper and Schmid (2006, p.2) identified concentration as “focusing, not forcing, one’s attention on a task”. Concentration is a learned skill as to not be distracted by irrelevant stimuli and when one becomes distracted, it is having the previous concentration training to be able to quickly re-focus attention back to the competition and not continue or be re-distracted by the disturbance. Singer, Hausenblas and Jannelle (2001) stated that there is a difficulty to imagine that there can be anything more important to performance and learning of sport skills than paying attention.

For example, teams playing an away match in sports such as football and rugby can completely lose composure when they start to be heckled and when the noise of an arena heightens when they are taking important set plays such as corners, goal kicks, penalties and throw ins. Spectators may also hurl negative speech at the players which will distract them from the game. This shows the importance of mastering concentration seeing as these distractions can cause the downfall of many players and can cost them the match. Mastering the art of learning not to react or be disturbed by distraction is achieved when athletes master controlling their thoughts and correctly focus their attention.

Wilson, Peper and Schmid, (2006) found with more experienced athletes, an exercise called 'walk the walk' was beneficial. Here a coach walks the athlete through the set of play at least twice. They explain in detail to the athlete what they are doing in each segment of the play, and they break it up by distances, scores or beginning, middle and end. The coach then writes down key words or feelings for the segments and typically players will have already created a 'feeling' towards that segment of play. After running through the play a few times, athletes come up with better ways to express how that section of play makes them feel. These feelings can then be used as a coach to create positive affirmations to encourage and motivate athletes during competitive games to not lose focus and maintain concentration.

Researchers have identified that self-talk is an effective method of improving concentration when performing and the attention of self-talk can influence performance (Hatzigeorgiadis, Theodorakis and Zourbanos, 2004). It has been found that the most common aid to concentration was self-talk. It was found to be used more often in competition settings than practice settings (Hardy, Hall and Hardy, 2005). Experimental studies have taken place which identify the use of self-talk to aid concentration and attention in learning different performance skills. Chroni, Perkos and Theodorakis, (2007) identified the use of self-talk to aid concentration in leaning basketball skills and Goudas, Hatzidimitriou and Kikidi, (2006) also reported jumping and throwing track and field events to be aided through self-talk. This shows self-talk and concentration to be positively correlated with one another in improving performance parameters.

However, it has been suggested that self-talk also brings negative thoughts to mind which can also cause a detriment to performance. This was found from the results of a study by Hatzigeorgiadis, Theodorakis and Zourbanos, (2004) which included an instructional group, a motivational group and a control group and the effect of self-talk and occurrence of interfering thoughts on water polo tasks. It was found that less negative thoughts were identified in the motivational and instructional self-talk groups when compared with the control group. They put this down to a lack of concentration during execution of tasks in the control group. This still shows a positive correlation between self-talk and concentration, particularly as performance improved because of increased concentration. It is possible that the negative thought is in fact an indirect measure of concentration and does not equal to improved concentration and performing better in the occurrence of positive thoughts. This study supports the effectiveness of self-talk having a positive influence on performance and can enhance concentration.

2.12 Challenge of evaluating Physical and Cognitive Characteristics

Sport participation for non-VI persons is important and can be highly beneficial to their physical and social health. This is equal if not more important for those with VI. Engaging in sport (e.g. regular training, competition and testing) can be challenging for VI participants. From a performance perspective, appraisals of physical fitness require careful consideration. Fitness tests are sometimes ecologically valid but not reliable and vice versa. Established field-based tests which are reliable tend to be unsafe for VI athletes. For example, this can include running and cycling tests where participants require spatial awareness, something which those with VI struggle with. As such with VI athletes, fitness tests tend to be prioritized around safety and reliability as opposed to ecological validity (i.e. relevant to the sport).

Internal and external spatial awareness is essential in Goalball. This is so that athletes can identify their position on the pitch, and this is guided via the raised lines. Seeing as visual information is blocked, athletes must have a high level of spatial awareness to be able to complete testing where things like running and sprinting are taking place. It has been identified that regular physical activity can provide potential improvements to VI persons spatial orientation (Seemungal *et al.,* 2007).

Uysal and Duger, (2011) also found those with better vision to have better motor skills such as coordination, balance, running and proficiency. This study was commenced amongst school children (30 children with low vision, 30 children with total VI and 30 children with full sight) and the Bruininks-Oseretsky Motor Proficiency Test was used to assess participants. When comparing the low vision group and total VI group, running, balance, coordination of upper limbs, response speed and total motor points had significant differences in favour of the low VI group ($p<0.05$) and those with full sight obtained the highest score across all tests. It was found those with VI were often left behind and therefore had lower motor skills due to the lack of visual stimuli. The results supported this in that visual stimulus reflected positively in the results with no VI scoring the highest possible score, followed by the low vision and finally by total VI. The study demonstrates an increased gap with age in motor skill development between different visual acuity children. Sport encourages a more independent life amongst VI persons through reducing the inevitable fear of environmental harm (Caliskan *et al.,* 2007). This highlights the importance of increasing spatial awareness in VI athletes and the difficulties which practitioners may come across in testing due to the reduction in motor skills.

2.13 The Proposed Study

The literature review above has explained the reasoning for the needs of this study to take place. Research by Krazk, Slezynska and Slezynski (2015) showed the need for motor skills to be investigated in Goalball between levels of performance. Whilst looking at sprint performance, research highlighted the need for evidence looking at the correlation between skills to aid performance. This helped to influence this research to look at the different variables relevant to Goalball and which aid performance the most. Lee, Lee and Park (2020) identified the importance that fatigue levels have on power performance. This helped guide this research to identify factors within Goalball which will influence performance and therefore will have an influence on fatigue levels which can be investigated in future research on the reduction of fatigue in these factors during competition. The shoulder is a complex area of the body which requires further investigation. This research paper will identify if shoulder strength influences performance. This can then be used should shoulder strength play a relevant role in Goalball to investigate which specific muscles of the shoulder influence performance the most and if any weaknesses within the shoulder joint cause injury. Samson (2005) highlighted the importance of the core in performance and its ability to transfer force between the upper and lower limb, which highlights the importance of investigating other skills which core stability may impact. Xiao *et al*., (2021) highlighted the importance of isolating muscle groups when measuring muscular endurance to avoid errors in research. This research will focus on the isolation of muscle groups when testing muscular endurance to avoid error. Goulart Siqueira *et al*., (2018) completed the Yo-Yo test with Goalball athletes however identified that the performance of Goalball athletes was lower than that of sighted athletes. This may be due to their VI causing anxiety and fear which reduced performance levels. This study will measure aerobic capacity by adding factors which will mean their VI does not affect performance.

This research paper will look at describing the physical and cognitive determinants of performance in Goalball players. The study was designed to determine the key physical characteristics of elite Goalball and if it is discriminated upon by cognitive characteristics. The research question in this project is ‘what physical characteristics have a positive difference on Goalball performance and does cognition aid or have a negative difference on physical performance, does this differ between levels of performance?’ This research can advance the knowledge area within Goalball due to the current volume of literature being unsatisfactory. There is a need for standardization of specific tests for Goalball athletes ensuring recruitment of specific muscles and consistency to identify which athletes have potential to be elite and which areas require improvement to reach this goal. The aim of this research is to create a novel study which identifies which characteristics of performance are most relevant to Goalball and if so, which physical characteristics are different between levels of performance. This will help to fill the gap in research for coaches to use tools which can identify those athletes which are more advanced than others and which have potential to become elite. It will also aid coaches in the recruitment process on which characteristics are most applicable to a Goalball game and give them a guide on things they want to look out for. It will help athletes to correctly condition themselves as they will know which characteristics of sport are most important to improve to progress to be elite.

3.0 Methods

3.1 Research Design

During this study, a quantitative cross-sectional design was used. The cross-sectional design was used due to the fact it is a quick and inexpensive way to complete research. All data was collected on one occasion which increased feasibility for athletes as well as the fact multiple outcomes could be measured and studied from one testing session (Wang and Cheng, 2020). This results in many findings to create an in-depth study. Due to the challenging nature of the sample, a cross-sectional design was agreed at priori with the research team and Goalball practitioners. This looked at comparing High-Performance, Talent and Academy Goalball UK players completing the same physical and cognitive tests on one occasion. A cross-sectional design is easy to conduct as participants are tested on one singular occasion which increases the feasibility for these participants due to their VI.

3.2 Participants and sampling

A total of 25 male and female UK-based Goalball players were recruited to voluntarily participate in this project investigating the characteristics it takes to be elite in Goalball. To conduct this research, the performance pathway from Goalball UK was used to differentiate playing levels. 10 of these players were High-Performance athletes which meant they were currently at the highest level of the UK Goalball performance pathway. 5 players were Talent athletes, the next stage in the pathway and finally 10 players were Academy based, the lowest stage of the pathway. This can be seen in Figure 1. Participants were aged 13 - 34 with a mean and standard deviation of 20.28 ± 5.86. The mean weight and standard deviation of participants was 73.89 ± 19.71 with a range of 37.5 - 115.9kg. The mean height and standard deviation of participants was 170.12 ± 10.53 with a range of 141.5 - 188.9. To participate in this research, all participants must have played for the organisation Goalball UK for a minimum of one year and their level of VI must be either B1, B2 or B3, the requirements to play Goalball internationally. Participant information can be found in Table 1.

Participants were recruited through non-probability sampling. This was purposive so the participants would have the shared characteristics relevant to the research question. This is since participants must be visually impaired Goalball players to participate as they are the only population which exhibit the qualities relevant to the research question. The number of participants recruited was based upon the percentage of players available and uninjured from the organisation Goalball UK. Twenty-five out of a possible thirty-one athletes participated in testing. This was equivalent to 80.65% of athletes from the Goalball UK Performance Pathway in 2023-24 and ten out of thirteen of these players were High-Performance players. Participation in this project was voluntary, and all participants gave written informed consent prior to the conduction of research. Unique identification codes were provided to ensure all participants remained anonymous (i.e., HP1, HP2, T1, T2, A1 and A2). ID codes were determined by level of performance followed by a random number. Prior to data collection, ethical approval was obtained and approved by the York St John Ethics Committee (reference number: ETH2324-0404).

	No. of Participants:	**Age range: Mean ± Standard Deviation (SD) Range**	**VI Classification**
High-Performance	10	26 ± 4.78 19 – 34	B1- 0 B2- 9 B3- 1
Talent	5	18.6 ± 2.3 16 - 22	B1- 1 B2- 0 B3- 4
Academy	10	15.4 ± 1.43 13 - 17	B1 – 1 B2 – 4 B3 - 5

Table 1: Participant information

3.3 Procedure

Participants took part in various physical and cognitive tests exploring the relevant physical and cognitive characteristics to Goalball. First, VI instruction training was undertaken to enhance the quality of communication with athletes. The testing took place at familiar indoor facilities where participants would typically play Goalball on their training camps which replicated a typical environment in which participants would play Goalball. The testing took part in two different locations to increase feasibility for participants. These locations were The English Institute of Sport, Sheffield and The Factory, Birmingham. Participants were run through all exercises verbally and physically as means of familiarisation. Techniques were corrected and participants had practice runs prior to completing testing to ensure all exercises were understood. This helped to also reduce anxiety levels within participants regarding what exercises they would be completing, allowing them to be confident in giving 100% maximal effort without fear. All tests covered performance characteristics relevant to Goalball including Aerobic capacity, Speed, Lower limb Power, Endurance and Strength. The idea was to look at whether these characteristics had a significant difference on level of performance. It also looked at whether cognitive characteristics weigh in and have either a positive or negative difference on physical characteristics within performance. As seen in the literature, these components play a large part in not only Goalball but sports with similar characteristics. The tests included in this research have a replication to a variety of sports which also use and test these characteristics. A pilot testing session was conducted to ensure all exercises were viable and to ensure they are suitable for VI participants. Prior to completing testing, participants completed a standardized ten-minute dynamic warm up. This included running, lunges, squats, shoulder circles, shoulder stretches, hamstring and quad stretches, calf stretches, sprint practices and horizontal and vertical jump practice.

3.4 Measures

3.5 Cognitive ability: concentration, orientation and cognition

To test participants cognitive ability, the Sports Concussion Appraisal Tool 6th version (SCAT 6) part three: cognitive screening was used. The SCAT 6 is a multimodal tool to look at assessing participants across several domains of functioning (Echemendia *et al*., 2023). Weiler *et al*., (2024) discussed the lack of literature on concussion in para sports. Previously, the same guidelines have been used nationwide in the view that all athletes have the same cognitive and neuromuscular functions. This looks at the SCAT 6 being used globally for all athletes, in both para and non-para sports. This part of the test looks at participants orientation, immediate memory and concentration. The questions asked to the participants can be seen in the appendix. Participants answered all questions and a score out of forty was made based on number of questions correctly answered. This type of cognitive testing was chosen due to accessibility and the fact that participants can have the questions read to them. The total score reported was out of a maximum of forty as per the SCAT 6. A score of forty was the best score athletes could achieve. Zero was the lowest score athletes could achieve.

The SCAT 6 was designed similar to the SCAT 5 with revised read aloud assessment to make the SCAT 6 more accessible. The SCAT 6 does however still contain a visual tracking assessment. This study has used the SCAT 6 part three: cognitive screening which does not include visual tracking assessment which makes it more accessible for VI athletes. It has been found that the SCAT 6 is facilitative to accurately assess VI athletes (Law *et al.,* 2025). They identified for the visual tracking assessment; athletes may benefit from the testing when clinicians use larger and light-based pointers during assessment. Weiler *et al.,* (2018) identified that VI footballers scores during the SCAT 3 did not have a significant difference from sighted players.

The SCAT 6 was chosen to use over other cognition tests specifically designed for VI participants since it was a pragmatic decision agreed at priori with the supervisory team and Goalball practitioners on the context and needs of the athletes. The SCAT 6 has been previously used on this group of athletes so a familiarisation process was not required and is more realistic to the needs of the research, focusing on concentration, memory and orientation. Other cognition tests such as the Montral Cognitive Assessment (MoCA) were discussed however for pragmatic and imperial reasons, the SCAT 6 has been used as a tool within the VI population and has been deemed a more sport specific measure in relation to Goalball.

The first two sections of the MoCA require visual assessment. Dawes *et al*., (2019) identified that the MoCA would be suitable for adaption for VI athletes however not for those which have both hearing and visual impairments. The results presented by Wittich *et al*., (2010) show that the MoCA can be used successfully when screening VI persons. They explained that the test must be used with caution until improvements are made to increase sensitivity to higher than 80% when it is used without questions which require vision. For this reason, the current study has proceeded to use the SCAT 6: Part 3 which requires no adaption to use.

3.6 Sprint performance

The next test was a 3-metre sprint which was used to represent sprint performance and short sprint quality (Pyne *et al.,* 2008). This involved participants starting on the floor in their standard defensive positions and upon hearing GO and clapping from the end of the court, participants performed a maximal 3 metre sprint through witty timing gates. This is designed to replicate the transition from the defensive to attacking phase in Goalball. The 3-metre sprint replicates the distance from the defensive line up to the throw line. A standardised start position 0.3 metres from the 3-metre start line was in place (Altmann *et al.,* 2015). Gates were then placed at the start of the 3-metre start line and at the end of the 3-metre line at 1 metre height. Gates were kept at a consistent height of 1 metre throughout the testing as it has been found that timing gate height can significantly affect performance results (Cronin and Templeton, 2008). This ensured that only one part of the body would activate the gates from the moment the participant passed through the timing gates (Yeadon, Kato and Kerwin, 1999). The time between the two gates measures sprint time. At the far end of the pitch a coach stood and shouted/clapped to the participant to provide auditory guidance in relation to the direction of the sprint. Three trials took place with 60 seconds active recovery between trials. The average was then worked out from the trial. The average score was used to make scoring realistic to Goalball as participants may not consistently be their fastest the longer the match goes on. Therefore, it is important to consider measures of fatigue in sprint time.

Witty Electronic timing gates (Witty system, Microgate, Bolanzo, Italy) were used to ensure sprint times were accurate and this was important so that efficacy was ensured. Repeated sprint testing with active recovery has been presented as very reliable when measuring total sprint time (Spencer *et al.,* 2006). Another study identified repeated shuttle sprint ability showed as valid and reliable in observing large training-induced changes however does not identify the smaller more important differences (Impellizzeri *et al.,* 2008).

3.7 Lower limb Power

The countermovement jump (CMJ) is a version of a vertical jump derived from the Sargent jump (Sargent, 1921). The test represents a reliable measure of explosive lower limb power and the benefit of pre-stretch prior to jumping (Markovic *et al.,* 2004). In comparison to other jump tests, the CMJ has been shown to be the most reliable. It shares strong relationships with sprint performance, explosive strength tests and maximal strength (Stojanovic *et al.,* 2012; Young, Cormack and Crichton, 2011). It has been suggested that participants who perform better in the CMJ also tend to perform better in sprint performances. When arm swing is included in CMJ, performance increases by >10% (Cheng *et al*., 2008). To make the test examine purely lower limb plyometric power and strength, arm swing was not permitted. This is because it was found that the inclusion of arm swing can improve performance parameters which then causes the test to not be based purely on lower limb power/strength, reducing the efficacy (Shadmehr *et al*., 2016). However, Heishman *et al.,* (2020) found including arm swing can provide more significant information regarding long-term changes in sporting performance within both the upper and lower limb. The test was measured using Hawkins Portable Force Plates (Hawkins Dynamics, USA) which can be used as an appropriate alternative to the in ground 'gold standard' force plates when testing CMJ performance (Badby *et al.,* 2022). Participants stood on the force plate and bent at the knees into a countermovement before launching themselves upwards using a toe-off phase into the air aiming to land in the same zone. To ensure participants land in a similar position, a foam surround was used around the force plates so participants could familiarise themselves with the landing area through the different textures between the force plates and the foam surrounds. Participants were required to hold hands on their hips, as to not cause any advantages. Three jumps were recorded to calculate average jump height. Participants received two minutes active recovery following each jump. Extension of the lower limbs at the hip knee and ankle were noted during the exercise as flexion of these areas can increase jump height and therefore invalidate data. Participants must give full effort as sub-maximal efforts will result in inaccurate results.

3.8 Shoulder strength

The Athletic Shoulder Test (ASH) assesses isometric shoulder strength. The test was originally developed to evaluate neuromuscular activity within the shoulder girdle during contact sport (Ashworth *et al.,* 2018). Seeing as participants within Goalball typically perform push manoeuvres when throwing the ball, this test occurred with participants laying in prone to generalize the test to Goalball. An isometric based strength training device called a Microfet (Hoggan Scientific LLC, USA) was used to measure isometric shoulder strength. Participants rested their forehead upon a foam mat face down on the floor. The test involved the participant pushing down maximally for 3 seconds in three different positions. The test was completed on both the left and right sides of the body. These positions being an I position, a Y position and a T position. The I test is placed at 180 degrees in full abduction with the forearm pronated and the elbow fully extended in each test position. The rest arm is placed by the side of the participant's body. The Y test has the shoulder positioned at 135 degrees. In this position, the contralateral arm is placed behind the participants back. The final T test is positioned with the shoulder at 90 degrees. Once again in this position, the opposite arm is placed behind the participants back. The Microfet was used in this test rather than 'gold standard' force plates to increase the feasibility of completion for VI participants as well as the fact it is also more portable. Participants completed three repetitions (reps) in each position with one minute rest between reps. It was found when comparing the Microfet with the use of force plates for this test, that both were reliable tools and results from the two devices largely correlated with one another (Krolikowska *et al.,* 2022).

3.9 Maximal strength

To test maximal full body strength and force production capabilities, the isometric mid-thigh pull (IMTP) test took place. This test allows participants to produce a greater force than that of a maximal concentric action. This exercise is a safer alternative for those with VI as it is a simple movement and does not require compromising body positions. Therefore, this test is used to measure maximal full body peak force in regard to body strength and power. To measure the peak force produced from this test, Hawkins Portable Force Plates (Hawkins Dynamics, USA) were used. These will be that of the same from the counter movement jump so participants will be familiar with the force plates. This test required the participant to pull upwards on a fixed barbell for 5 seconds with maximal effort and participants completed two reps with 2 minutes rest in between. A deadlift stance was assumed and a hip angle of 145 degrees was recommended to be the most optimal position for participants. All participants received a test pull prior to the real test.

Giles, Lutton and Martin (2022) found the IMTP to be supported in being used for testing in dynamic performance assessments. They found that due to the fact many sports require multiple bio-motor abilities to be tested, the IMTP is advantageous due to its strong correlations to multiple dynamic sport assessments and performance metrics. Guppy *et al.,* (2018) conducted a review which confirmed the IMTP as a reliable and efficient measure of participants maximum force generating capacity and rate of force development. Another scoping review by Giles, Lutton and Martin, (2022) found strong correlations between the IMTP and dynamic performance parameters. They identified that the IMTP should be adopted into assessment batteries in sport and that it is a viable option for athletic ability profiling.

3.10 Core stability

The Glute Bridge looks at core stability of participants. This exercise focuses on the core and posterior muscles of the hip. The single leg Glute Bridge incorporates the activation of stabilizing muscles (Tobey and Mike, 2018). To perform the test, participants started in a supine position. They then brought the working leg toward the hips so that the knee was at 90 degrees during hip extension. The non-working leg was lifted, and the hip and knee were flexed so that the leg was 'tucked'. The participant performed each rep to the beat of a 60bpm metronome. Each beat coincided with one movement (one beat to move down to bottom position, one beat to move up to top position). Full hip extension was to be achieved on each rep. The test finished when the participant failed to maintain correct form or missed two consecutive beats. Again, the structure for this test was most feasible for participants to take part in due to its simplicity and lack of use of equipment. Therefore, this test is easily replicable.

A systematic review and meta-analysis found metronome training combined with additional motor programmes to be valid in effectively improving various motor functions including motor skills in relation to timing properties or motor performance (Lee *et al.,* 2022).

3.11 Isometric Muscle Strength Endurance - Lunge

To test muscle strength endurance, an Isometric Lunge hold was performed. The lunge is an important factor to test seeing as multiple mechanics of the body are tested such as lower limb position, balance, stability of the upper body and core stability which can affect prime and stabilizer muscles of the legs (Marchetti *et al.*, 2018). A lunge movement is often used in Goalball when participants are throwing the ball. Participants held a static lunge position, with their hips level with their front knee. Participants were all checked for correct technique. A wall was used to aid balance with participants standing side on. Participants were not allowed to lean on the wall but were able to have a fingertip touch to help with balance but not to give an advantage. The position was held for up to 60 seconds. The test finished when the participant achieved 60 seconds hold or lost form.

Isometric holds are a safe and efficient method of testing. Particularly when working with complex participants. The testing therefore would have been relatively easy for participants to understand. A study investigated the validity of isometric strength tests. Isometric strength test validity was demonstrated by meta-analyses results. They found the results of six validity studies confirmed isometric strength tests as valid predictors of physical performance and this can be generalized (Blakley *et al.,* 1994).

3.12 Isometric Muscle Strength Endurance – Hamstring hold

The Hamstring hold measured participants muscular endurance of the hamstring. This test took place as it was easy for participants to understand as well as the fact no equipment was needed to be used making it easily replicable. Participants started by laying in a supine position. The heel of the working leg was pushed in to the ground at around 130 degrees knee flexion. The non-working leg was lifted, and the hip and knee were flexed so the leg was 'tucked'. On the sound of 'go', the working leg was fully extended driving the heel in to the ground and lifting the buttocks and a static position was held. The test ended when the participant achieved 60 seconds or when form was lost.

It has been identified that isometric contractions can be more useful in improving muscle strength and endurance than eccentric contractions and flexibility (Stasinopoulos and Stasinopoulos, 2017) and therefore is a popular method of increasing hamstring strength and endurance. Isometric training has been shown to alter physiological characteristics including architecture of muscle, metabolic activity and joint angle specific torque (Noorkoiv, Nosaka and Blazevich, 2015; Schott, McCully and Rutherford, 1995). It was found that isometric exercises allow the muscle to maintain its resistance ability against force, it provides an effective simple approach to improve the hamstring muscles and during activity, can increase hamstring resistance and power (Widodo *et al.*, 2022).

3.13 Aerobic Capacity

To analyse aerobic capacity, a 12-minute stationary cycle was performed. This test was performed using a Watt Bike (Watt Bike Ltd, UK). A Watt Bike was used rather than a standard road bike to assist with participants VI and to not add extra challenging characteristics such as wind speed, traffic or unfamiliar terrains which may reduce participant scoring. The Watt Bike load was selected based on Watt Bike recommendation which was based on participant body mass. Participants completed a 3-minute steady warm-up on the bike prior to the test. Participants then had 12 minutes to cover as much distance as possible. Pacing was self-selected with advice and motivation provided from coaching staff for all participants. Distance was recorded from this. Originally, this test was performed by Vanderburgh (1993) who found it to be an efficacious maximum rate of oxygen consumption peak prediction test for college age men and women. They noted the test is best applied to highly motivated and capable subjects. They confirmed it to be a good way of measuring fitness levels based on maximal sustained effort. There is a lack of research on this test when investigating VI participants. This test is not 'gold standard' laboratory gas analysis however it is the most feasible and least intrusive way when working with VI participants. The 12-minute stationary cycle allowed for a more accurate expression of aerobic capacity vs ambulatory tests to eliminate change of direction and potential fear of collision.

3.14 Data analysis

There were several stages of analysing data. Data was analysed using Jeffreys Amazing Statistic Program 0.16.3 (JASP) with alpha level set at $p<0.05$. First, all data was inputted in to a excel document which was cleared and checked for any missing values. Participants were broken up into groups based on their level of performance. These were 10 High-Performance participants, 5 Talent participants and 10 Academy participants. If participants had <40% data, they were excluded from research. This was the case for two participants. Participants with >40% data were able to take part in the research. Second, data was then inputted to JASP and the descriptives including mean, standard deviation (mean ± SD) and range were then reported. An ANOVA was then performed to identify differences between the levels of performance and the physical characteristics which have a significant difference between groups. Visual inspection of QQ plots confirmed normal distribution between performance levels and homogeneity between groups. A post-hoc Bonferroni adjustment was then conducted to identify significant differences between groups as well as effect sizes. Confidence interval was set at 95% and Cohen-d (inference) was set as follows: 0.2 = trivial difference, 0.2 – 0.5 = small difference, 0.5 – 0.8 = moderate differences and >0.8 = large differences. This measures the magnitude of difference between the relevant groups (Cohen, 1988).

4.0 Results

This paper looked at the characteristics which have a positive difference on Goalball performance and whether there was a discrimination between levels of performance. Two data sets were excluded from data analysis due to the lack of data <40% collected. Final data analysis looked at 25 Goalball UK athletes in total, these were 10 High-Performance athletes, 5 Talent athletes and 10 Academy athletes.

4.1 Descriptive results

Participant age range differed from 13 – 34 with a mean and standard deviation of 20.28 ± 5.86. All athletes were fit for participation. Height differed across participants from 141.5 – 188.9 cm (170.12 ± 10.53). The shortest athlete was identified in the Academy group (141.5cm) and the tallest athlete was identified in the High-Performance group (188.9cm). Weight differed from 37.5 – 115.9 kg (73.89 ± 19.71). The lightest athlete was noted in the Academy group (37.5kg) and the heaviest athlete was noted in the High-Performance group (115.9kg). Leg length differed from 92 – 205 cm (119.42 ± 25.59). Athletes with the longest legs were noted in the High-Performance group (205cm) and the shortest leg length was noted in the Academy group (92cm). Arm span differed from 152 – 205 cm (180.35 ± 14.64). The athletes with the longest arms were noted in the High-performance group (205cm) and the athlete with the shortest arms was noted in the Academy group (152cm). Statistic Descriptives are shown in Table 2.

The SCAT 6 had an overall mean and standard deviation of 30.88 ± 4.74 with a range of 19-38. The maximal score possible for this test was 40. The lowest score was noted in the Academy group and the highest score was noted in the High-Performance group. Overall sprint time had a mean and standard deviation of 1.28 ± 0.27 and a range of 0.75 – 1.69s. The fastest sprint time was noted in the High-Performance group and the slowest sprint time was noted in the Academy group. The countermovement jump had a mean and standard deviation of 29.21 ± 7.80. The range in this test was 13 – 43cm. The smallest jump height again was in the Academy group and the highest jump height was in the High-Performance group. The IMTP ranged from 1423 – 2920N. The highest score was found in the High-Performance group and the lowest score was found in the Talent group. The Academy group did not take part in this test. This test had a mean and standard deviation of 2222.15 ± 443.51.

The ASH test (left) had a mean and standard deviation of 100.52 ± 31.22. The range in this test was 54.53 – 175.2N. The highest score was noted in the High-Performance group and the lowest score was noted in the Academy group. This was the same for the ASH test (right). The range in this test was 54.83 – 192.53N. The mean and standard deviation of this test was 106.65 ± 34.60. The 12-minute cycle test had a mean and standard deviation of 7.15 ± 0.48. The range of this test was 6.39 – 7.91km. Both the highest and lowest scores of this test were noted in the High-Performance group. The Academy athletes did not complete this test. The isometric lunge test (left) had a mean and standard deviation of 58.64 ± 4.74 and a range of 41 – 60s. All High-Performance and Talent athletes achieved a score of 60 in this test as well as some Academy players and the lowest score in the Academy group was 41. The Isometric Lunge test (right) had a mean and standard deviation of 59.64 ± 1.25. The scores ranged from 44 – 60s. All participants in the High-Performance and Talent groups achieved a score of 60 as well as some athletes in the Academy group. The lowest score was noted in the Academy group. The Isometric Hamstring test (left) had a mean and standard deviation of 58.05 ± 4.54 as well as a range of 44 – 60s. Interestingly, the lowest score in this test was noted in the High-Performance group and the highest score of 60 was shared across all three groups. This was similar to the Isometric Hamstring (right) test. The scores in this test ranged from 13 – 60s. The lowest score was noted in the Academy group and the highest scores were shared across all three groups. The mean and standard deviation of this test was 54.71 ± 12.39. The Metronome Glute Bridge (left) had a mean and standard deviation of 43 ± 22.03. The scores ranged from 2 – 84 reps. The lowest score was noted in the Academy group and the highest score was noted in the High-Performance group. This was similar to the Metronome Glute Bridge (right) which had a range of 3 – 84 reps. The Academy group had the lowest score, and the High-Performance group had the highest score. The mean and standard deviation in this test was 40.71 ± 24.87.

Variable	Overall (Mean ± SD) (Range) (*N*=25)	High-Performance (Mean ± SD) (Range) (*N*=10)	Talent (Mean ± SD) (Range) (*N*=5)	Academy (Mean ± SD) (Range) (*N*=10)
Height (cm)	170.12 ± 10.53 141.5 -188.9	176.53 ± 8.28 162.1 – 188.9	171.22 ± 7.34 163 – 182.1	163.15 ± 10.16 141.5 - 178
Weight (kg)	73.89 ± 19.71 37.5 - 115.9	95.51 ± 17.32 58.6 – 115.9	64.82 ± 9.06 53.4 – 78.1	60.81 ± 11.02 37.5 – 80.4
Arm span (cm)	180.35 ± 14.64 152 - 205	193.44 ± 11.78 174.5 - 205	181.1 ± 10.98 169 - 197	169.5 ± 8.9 152 - 182
Leg Length (cm)	119.42 ± 25.59 92 - 205	135.16 ± 34.66 104 - 205	114.9 ± 4.48 108.5 - 121	105.95 ± 6.91 92 – 118.5
Age	20.28 ± 5.86 13 - 34	26 ± 4.78 19 – 34	18.6 ± 2.3 16 - 22	15.4 ± 1.43 13 - 17
Scat 6	30.88 ± 4.74 19 - 38	31.5 ± 3.81 26 - 38	31.8 ± 5.54 23 - 38	29.8 ± 5.43 19 - 34
Sprint time (s)	1.28 ± 0.27 0.75 - 1.69	1.04 ± 0.23 0.75 – 1.33	1.31 ± 0.1 1.2 – 1.46	1.5 ± 0.16 1.23 – 1.69
Counter Movement Jump (cm)	29.21 ± 7.80 13 - 43	34.3 ± 6.58 23.2 - 43	29.1 ± 4.63 23.8 – 34.6	24.2 ± 7.28 13 - 37
IMTP (N)	2222.15 ± 443.51 1423 - 2920	2411.9 ± 285.91 1941 - 2920	1589.67 ± 179.68 1423 - 1780	N/A N/A
ASH L (N)	100.52 ± 31.22 54.53 – 175.2	127.3 ± 26.98 86.1 – 175.2	96.134 ± 20.59 60 – 109.3	75.93 ± 14.28 54.53 – 95.73
ASH R (N)	106.65 ± 34.60 54.83 - 192.53	139.24 ± 26.56 111.2 – 192.53	101.62 ± 13.94 85.3 – 123.43	76.58 ± 14.23 54.83 – 94.43
12 Min Cycle (km)	7.15 ± 0.48 6.39 - 7.91	7.21 ± 0.52 6.39 – 7.91	6.98 ± 0.37 6.65 – 7.37	N/A N/A
Iso Lunge L (s)	58.64 ± 4.74 41 - 60	60 ± 0 60	60 ± 0 60	56.6 ± 7.23 41 - 60
Iso Lunge R (s)	59.64 ± 1.25 55 - 60	60 ± 0 60	60 ± 0 60	59.1 ± 1.91 55 - 60
Iso Hamstring L (s)	58.08 ± 4.54 44 - 60	57.33 ± 5.66 44 - 60	60 ± 0 60	57.8 ± 4.64 49 - 60
Iso Hamstring R (s)	54.71 ± 12.39 13-60	55.11 ± 7.75 40 - 60	60 ± 0 60	51.7 ± 17.69 13 - 60
Met Glute L (reps)	43 ± 22.03 2 - 84	54.33 ± 17.29 30 - 84	54 ± 13.49 43 - 75	27.3 ± 20.59 2 - 69
Met Glute R (reps)	40.71 ± 24.87 3 - 84	55.11 ± 16.79 32 - 84	51.2 ± 18.99 28 - 71	22.5 ± 23.09 3 - 67

Table 2: The Descriptive Statistics of the Dependent and Independent Variables.
Note: SD = Standard Deviation

Variable	High-Performance - Talent *p*-value Mean Diff, ±95% CI *Cohen-d (Inference)*	High-Performance - Academy *p*-value Mean Diff, ±95% CI *Cohen-d (Inference)*	Talent - Academy *p*-value Mean Diff, ±95% CI *Cohen-d (Inference)*
Scat 6	1 -0.30, -6.98 to 6.38 -0.06 (Trivial)	1 1.70, -3.76 to 7.16 0.35(Small)	1 2.0, -4.68 to 8.68 0.41(Small)
Sprint time (s)	0.047* -0.27, -0.52 to 0.01 -1.47 (Large)	<0.001*** -0.45, -0.66 to -0.24 -2.48 (Large)	0.23 -0.18, -0.43 to 0.07 -1.02 (Large)
Counter Movement Jump (cm)	0.49 5.19, -3.86 to 14.24 0.79 (Moderate)	0.007** 10.09, 2.70 to 17.48 1.53 (Large)	0.56 4.90, -4.15 to 13.95 0.75 (Moderate)
IMTP (N)	<.001*** 822.23, 431.44 to 1213.03 3.05 (Large)	N/A	N/A
ASH L (N)	0.043* 31.17, 1.71 to 60.62 1.46 (Large)	<.001*** 51.37, 27.33 to 75.42 2.40 (Large)	0.3 20.21, -9.25 to 49.66 0.94 (Large)
ASH R (N)	0.008** 37.61, 9.87 to 65.36 1.87 (Large)	<.001*** 62.66, 40.01 to 85.32 3.11 (Large)	0.1 25.05, -2.70 to 52.80 1.24 (Large)
12 Min Cycle (km)	0.5 0.24, -0.51 to 0.98 0.48 (Small)	N/A	N/A
Iso Lunge L (s)	1 2.00, -6.36 to 6.36 0 (Trivial)	0.34 3.40, -1.80 to 8.60 0.74 (Moderate)	0.58 3.40, -2.96 to 9.76 0.74 (Moderate)
Iso Lunge R (s)	1 1.67, -1.68 to 1.68 0 (Trivial)	0.34 0.90, -0.47 to 2.27 0.74 (Moderate)	0.58 0.90, -0.78 to 2.58 0.74 (Moderate)
Iso Hamstring L (s)	0.94 -2.67, -9.17 to 3.84 -0.58 (Moderate)	1 -0.47, -5.83 to 4.89 -0.10 (Trivial)	1 2.20, -4.19 to 8.59 0.48 (Small)
Iso Hamstring R (s)	1 -4.89, -22.51 to 12.73 -0.39 (Small)	1 3.41, -11.10 to 17.92 0.27 (Small)	0.72 8.30, -9 to 25.6 0.66 (Moderate)
Met Glute L (reps)	1 0.33, -25.21 to 25.88 0.02 (Trivial)	0.012* 27.03, 5.99 to 48.08 1.49 (Large)	0.042* 26.70, 1.61 to 51.79 1.47 (Large)
Met Glute R (reps)	1 3.91, -24.37 to 32.19 0.19 (Trivial)	0.006** 32.61, 9.32 to 55.91 1.62 (Large)	0.050* 28.70, 0.93 to 56.47 1.43 (Large)

Table 3: Bonferroni Post Hoc test for Dependent and Independent Variables.
Dependent Variable: Performance Level
*p<0.05
**p<0.01
***p<0.001

4.2 Differences between groups

See Figure 2 for characteristics which have a significant difference on Goalball performance between different levels of performance. Figure 2 provides a visual colour coded graph which helps to explain the significance of characteristics between groups which are relevant to Goalball. Data was analysed and from this, those characteristics with significance were drawn out as those relevant to Goalball performance. This was inputted into a graph which visually shows the significance of each characteristic between groups. Greatest significance was noted between the High-Performance and Talent groups in Maximal strength which suggests this characteristic is most relevant to Goalball. This was followed by Sprint Performance, Shoulder strength and Core Stability which were largely significant between the High-Performance and Academy groups. Interestingly, Core Stability and Lower Limb Power had no significant difference between the High-Performance and Talent groups. Sprint performance and Shoulder Strength both had some significance between the High-Performance and Talent group and Lower limb strength had some significance between the High-Performance and Academy groups. As well as this, Core Stability had some significance between the Talent and Academy groups. Sprint Performance, Lower Limb Power and Shoulder strength had no significance between the Talent and Academy groups.

4.3 Cognition

A one-way ANOVA was performed to compare the effect of the Scat 6 on Performance Level. The one-way ANOVA revealed that there was not a statistically significant difference in Performance Levels between at least two groups ($F(2) = 0.41$, $p = 0.663$). The Bonferroni post-hoc test for multiple comparisons indicated a non-significant difference between the High-Performance and Talent athletes ($p=1$), the High-Performance and Academy athletes ($p=1$) and between the Talent and Academy athletes ($p=1$). These results can be seen in Table 3.

4.4 Lower Limb Power

A one-way ANOVA was performed to compare the effect of the Counter Movement Jump on Performance Level. The one-way ANOVA revealed that there was a statistically significant difference in Performance Levels between at least two groups ($F (2) = 5.88$, $p = 0.009$). The Bonferroni post-hoc test for multiple comparisons indicated that the mean value of the Counter Movement Jump was not statistically significant between the High-Performance athletes and Talent athletes (p=0.49) or between the Talent athletes and Academy athletes (p=0.56). A statistically significant difference however was found between the High-Performance athletes and Academy athletes (p=0.007, 95% C.I. = 2.70, 17.48). These results can be seen in Table 3.

4.5 Sprint performance

A one-way ANOVA was performed to compare the effect of Sprint Times on Performance Level. The one-way ANOVA revealed that there was a statistically significant difference in Performance Levels between at least two groups ($F (2) = 14.66$, $p = <.001$). The Bonferroni post-hoc test for multiple comparisons indicated that the mean value of Sprint Time was not statistically significant between the Talent and Academy athletes (p=0.23). However, a statistically significant difference was found between the High-Performance and Talent athletes (p=0.047, 95% C.I. = -0.52, 0.01) and between the High-Performance and Academy athletes (p=<.001, 95% C.I. = -0.66, -0.24). These results can be seen in Table 3.

4.6 Maximal Strength

A one-way ANOVA was performed to compare the effect of the IMTP on Performance Level. A one-way ANOVA revealed that there was a statistically significant difference in Performance Levels between at least two groups ($F (1) = 21.45$, $p = <.001$). The Bonferroni post-hoc test for multiple comparisons indicated that the mean value of the IMTP was significantly different between the High-Performance athletes and Talent athletes (p=.001, 95% C.I. = 431.44, 1213.03). The Academy athletes did not complete this test. These results can be seen in Table 3.

4.7 Shoulder Strength

A one-way ANOVA was performed to compare the effect of The Athletic Shoulder Test (Left) on Performance Level. A one-way ANOVA revealed that there was a statistically significant difference in Performance Levels between at least two groups (F (2) = 14.529, *p* = 001). The Bonferroni post-hoc test for multiple comparisons indicated that the mean value of The ASH (Left) test was not statistically significant between the Talent and Academy athletes (*p*=0.3). A statistically significant difference was found however between the High-Performance and Talent athletes (*p*=0.043, 95% C.I. = 1.71, 60.62) and between the High-Performance and Academy athletes (*p*=.001, 95% C.I. = 27.33, 75.42).

A one-way ANOVA was performed to compare the effect of The Athletic Shoulder Test (Right) on Performance Level. A one-way ANOVA revealed that there was a statistically significant difference in Performance Levels between at least two groups (F (2) = 24.330, *p* = <.001) The Bonferroni post-hoc test for multiple comparisons indicated that the mean value of The ASH (Right) test was not statistically significant between the Talent and Academy athletes (*p*=0.1). A statistically significant difference was found however between the High-Performance and Talent athletes (*p*=0.008, 95% C.I. = 9.87, 65.36) and between the High-Performance and Academy athletes (*p*=.001, 95% C.I. = 40.01, 85.32). These results can be seen in Table 3.

4.8 Aerobic Capacity

A one-way ANOVA was performed to compare the effect of The12 minute Cycle on Performance Level. A one-way ANOVA revealed that there was not a statistically significant difference in Performance Levels between at least two groups (F (1) = 0.50, *p* = 0.496). The Bonferroni post-hoc test for multiple comparisons indicated that the mean values of the 12-minute Cycle was not statistically significant between the High-Performance and Talent athletes (*p*=0.5). Academy athletes were not tested. These results can be seen in Table 3.

4.9 Muscular Endurance - Lunge

A one-way ANOVA was performed to compare the effect of The Isometric Lunge (Left) on Performance Level. A one-way ANOVA revealed that there was not a statistically significant difference in Performance Levels between at least two groups (F (2) = 1.622, *p* = 0.220). The Bonferroni post-hoc test for multiple comparisons indicated that the mean values of The Isometric Lunge (Left) was not statistically significant between the High-Performance and Talent athletes (*p*=1), between the High-Performance and Academy athletes (*p*= 0.34) and between the Talent and Academy athletes (*p*=0.58).

A one-way ANOVA was performed to compare the effect of The Isometric Lunge (Right) on Performance Level. A one-way ANOVA revealed that there was not a statistically significant difference in Performance Levels between at least two groups (F (2) = 1.625, *p* = 0.220). The Bonferroni post-hoc test for multiple comparisons indicated that the mean values of The Isometric Lunge (Right) was not statistically significant between the High-Performance and Talent athletes (*p*=1), between the High-Performance and Academy athletes (*p*= 0.34) and between the Talent and Academy athletes (*p*=0.58). These results can be seen in Table 3.

4.10 Muscular Endurance – Hamstring hold

A one-way ANOVA was performed to compare the effect of The Isometric Hamstring Hold (Right) on Performance Level. A one-way ANOVA revealed that there was not a statistically significant difference in Performance Levels between at least two groups (F (2) = 0.739, *p* = 0.490). The Bonferroni post-hoc test for multiple comparisons indicated that the mean values of The Isometric Hamstring Hold (Right) was not statistically significant between the High-Performance and Talent athletes (*p*=1), between the High-Performance and Academy groups (*p*=1) and between the Talent and Academy athletes (*p*=0.72).

A one-way ANOVA was performed to compare the effect of The Isometric Hamstring Hold (Left) on Performance Level. A one-way ANOVA revealed that there was not a statistically significant difference in Performance Levels between at least two groups (F (2) = 0.566, *p* 0.576). The Bonferroni post-hoc test for multiple comparisons indicated that the mean values of The Isometric Hamstring Hold (Left) was not statistically significant between the High-Performance and Talent athletes (*p*=0.94), between the High-Performance and Academy groups (*p*=1) and between the Talent and Academy athletes (*p*=1). These results can be seen in Table 3.

4.11 Core Stability

A one-way ANOVA was performed to compare the effect of The Metronome Glute Bridge (Left) on Performance Level. A one-way ANOVA revealed that there was a statistically significant difference in Performance Levels between at least two groups (F (2) = 6.399, *p* = 0.007). The Bonferroni post-hoc test for multiple comparisons indicated that the mean value of Metronome Glute Bridge (Left) test was not statistically significant between the High-Performance and Talent athletes (*p*=1). A statistically significant difference was found however between the High-Performance and Academy athletes (*p*=0.012, 95% C.I. = 5.99, 48.08) and between the Talent and Academy athletes (*p*=.042, 95% C.I. = 1.61, 51.79).

A one-way ANOVA was performed to compare the effect of The Metronome Glute Bridge (Right) on Performance Level. A one-way ANOVA revealed that there was a statistically significant difference in Performance Levels between at least two groups (F (2) = 7.085, *p* = 0.004). The Bonferroni post-hoc test for multiple comparisons indicated that the mean value of Metronome Glute Bridge (Right) test was not statistically significant between the High-Performance and Talent athletes (*p*=1). A statistically significant difference was found however between the High-Performance and Academy athletes (*p*=0.006, 95% C.I. = 9.32, 55.91) and between the Talent and Academy athletes (*p*=.05, 95% C.I. = 0.93, 56.47). These results can be seen in Table 3.

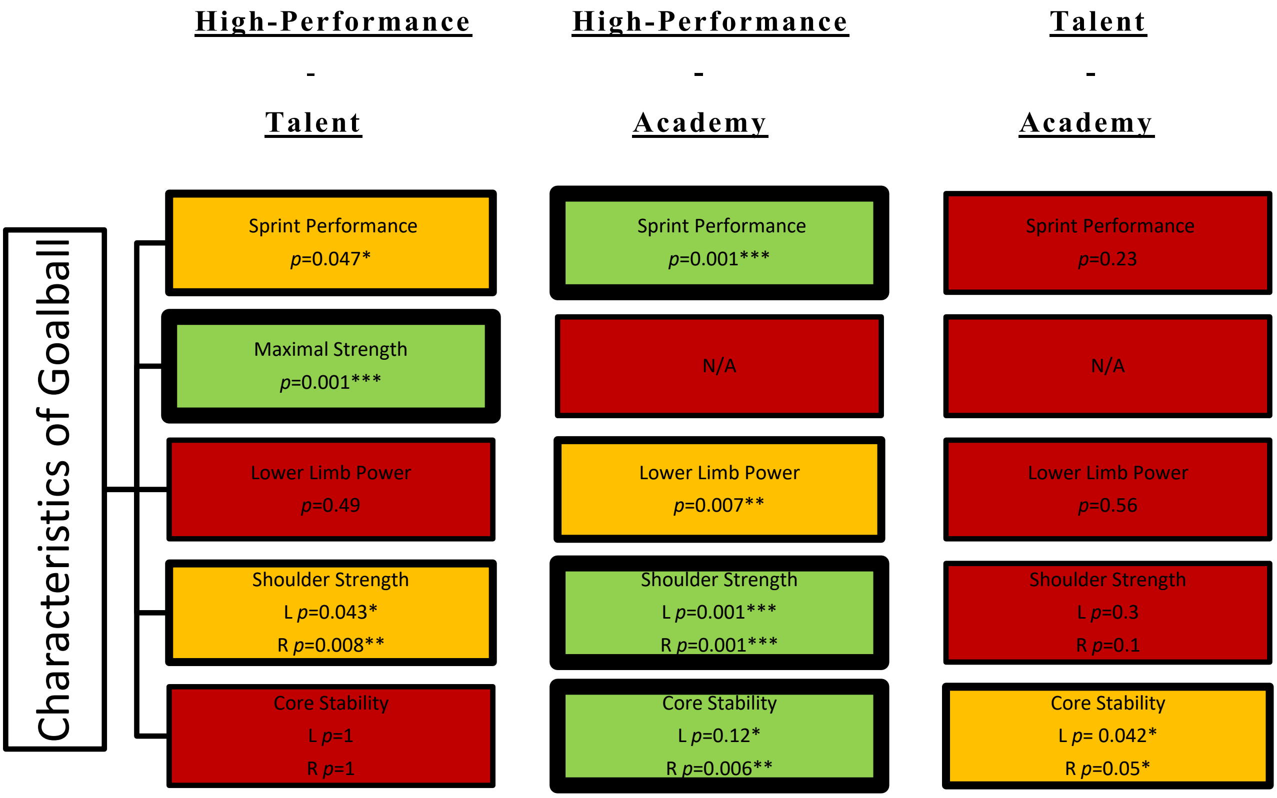

Figure 2: Characteristics which have a positive difference on Goalball and discriminate between performance levels. The weight of the lines presented in this figure relate to the magnitude that they discriminate between levels of performance. Figure is colour coded. Red = non-significant >0.05, Orange = Significance <0.05 - >0.005, Green = Significance <0.005.

5.0 Discussion

The aim of this novel study was to explore the differences in physical and cognitive characteristics between different levels of performance and whether they have a positive or detrimental difference on performance. This study is unique in the fact that physical and cognitive characteristics have not been researched together previously in Goalball. Physical and cognitive characteristics tend to go hand in hand, but this has not been discussed in a VI population. This study therefore provides novel and unique findings which can aid performance decisions in Goalball and support further research.

The study was designed to determine the key physical characteristics of elite Goalball and if cognition also played a part in affecting these physical characteristics. Lower Limb Power, Sprint performance, Maximal Strength, Shoulder Strength and Core Stability were all found to be statistically significant and can be identified as significant characteristics to improve performance in Goalball. This was a cross-sectional study, and participants were recruited through non-probability sampling. The hypothesis was that the higher the level of play (High-Performance, Talent and Academy) the better the athlete would perform. Contrary to our initial hypothesis, athletic performance level was not affected physically by Aerobic Capacity and Muscle Endurance as results were reported to be non-significant. Cognition also had no significant difference on performance level. Future research should examine the standard error and reliability regarding each test based on Goalball and para sports. This could include identifying the meaningful difference between groups and which tests are feasible for athletes to complete without error occurring from fear or anxiety.

When compared to the research identified in the literature review, results from this study would've been expected to show alternate findings (Ribiero-Alves *et al*., 2018; Alves *et al*., 2018; Gullick and Malone, 2011; Santos *et al*., 2018). The difference in the results in this study may have been affected by a small sample size. As well as this, some tests were not completed by all participants which may have had a large effect. By investigating these variables in Goalball, this can identify transferrable skills across sports. For example, it may be recognised that athletes with good levels of Maximal strength, Shoulder strength, Lower limb Power, Core stability and Sprint performance in handball or volleyball may find they excel at a sport like Goalball due to the known attributes relevant to the sport. This can guide coaches in the scouting process to identify not only existing Goalball players but also those who have the potential to excel in Goalball whilst they currently or have played another sport.

Figure 3 shows these statistics as all the characteristics which can influence Goalball which also discriminate between performance level and therefore may guide coaches in the recruitment process when looking at the elite players across specific level of performance. The idea is that the higher the level of performance, the better the performance of the athlete in that characteristic. The weight of the lines presented in this figure relate to the magnitude that they discriminate between levels of performance. For example, High-Performance athletes should have the best results in tests of Sprint performance, Maximal strength, Shoulder strength, Lower limb Power and Core Stability as these characteristics have been identified as those which have the largest impact on elite Goalball. These results suggest that certain areas of performance in Goalball may not be seen as essential and therefore are overlooked. This should be adapted and training programs specific to the characteristics identified in this study should be prescribed. This study is unique in the fact it measures both physical and cognitive characteristics in Goalball as well as their discrimination between performance levels, something which has not been investigated previously in Goalball. This provides coaches and athletes with stepping stones through the pathway with results as to which scores athletes should be hitting in the relevant characteristics to their level and which characteristics tend to be neglected in training. Considering the paucity on evidence in para sports and especially VI sports, inference will also be drawn from mainstream non-para sports. As such, research from other sports is used to compare findings.

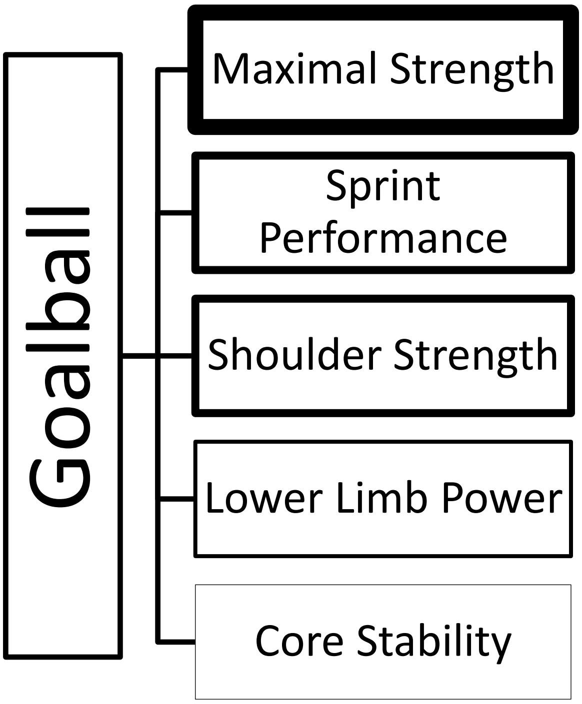

Figure 3: Summary of significant findings. The larger the weight of line, the more significant that characteristic is in relation the Goalball.

5.1 Lower Limb Power

Lower Limb Power was identified as being statistically significant in this study between the High-Performance athletes and the Academy athletes. No significant difference was found between the High-Performance and Talent athletes or the Talent and Academy athletes. To perform power movements, the segmental actions of the body are crucial and is determined by the interactions of net moments needed to be generated at the joints and the muscle forces to be in line with task demands (Rodacki, Fowler and Bennett, 2002). This is consistent with results from Goulart-Siquiera *et al.*, (2018) who investigated the CMJ in elite players and Colak *et al.*, (2004) who investigated CMJ in sub-elite athletes. Goulart Siqueira *et al.*, (2018) measured jump height in athletes. They reported better results among the elite athletes in the CMJ than those reported by Colak *et al.*, (2004) who also measured jump height. This is consistent with our results with the High-Performance athletes performing better than the Academy athletes. It has been identified that power performance is essential in Goalball through the actions of throwing and defensive attributes and that the energy contribution is provided by the alactic anaerobic metabolism (Alves *et al.*, 2018). Goulart Siqueira *et al.*, (2018) also identified significant relationships between the counter movement jump and aerobic capacity, throwing ability and muscle strength, all of which have been identified in this study as statistically significant features of Goalball across performance levels. Colak *et al.*, (2004) identified Goalball to be a continuous cycle of power and agility. They found that when comparing Goalball players to non-Goalball players that Goalball players attained better results ($p<0.05$). An essential component of this is the ability to transfer lower limb power to upper limb power in throwing. It has been identified that when throwing at high velocity's a critical component is the ability to transfer force from the lower body to the upper body to aid the force of the throw (Morriss and Bartlett, 1996). The transfer of power between the lower and upper limb is an essential component in most non-para sports which require upper limb and lower limb power. There is a lack of research investigating this in Goalball and therefore is a questioned component which requires future research to investigate the importance of power transference between limbs.

However, in terms of countermovement jump testing, Baktal (2008) investigated the effects of plyometric exercise on vertical jumping in female volleyball players. It was found that one season of plyometric training had no effect on vertical jumping, suggesting that training parameters to increase vertical jump performance needs to be researched. Atan and Ayca (2015) investigated the effect of Goalball on performance of VI students. Prior to testing, no statistically significant difference was identified between the two groups in vertical jump tests. However, following three months of testing, a significant difference was found in favour towards the exercise group which partook in Goalball ($p<0.05$) which indicates that Goalball requires a certain degree of power to be successful but could also be beneficial in vertical jump performance in many sports.

5.2 Sprint Performance

Sprint performance has been identified as a statistically significant factor of Goalball between the High-Performance and Talent athletes and the High-Performance and Academy athletes. No significant difference was found between the Talent and Academy athletes. This result was expected as seen earlier on in the paper many researchers have professed that Sprint Performance and Anaerobic capacity play a large part in Goalball performance. Jorgic *et al.*, (2019) conducted a 5 and 10 metre sprint performance test using witty timing gates. The study consisted of 12 Goalball players at national and international rankings. Their results identified the importance of the development of explosive lower and upper limb power and sprint performance. They identified these as important factors which can have a huge impact on throwing performance, another characteristic which has been identified as significant in this research project. Explosive strength and velocity can also have a huge impact on the counterattack from defence, taking opposition by surprise as they may have not assumed position yet, increasing chances of scoring. Seeing as the distance from the goal line to the high ball line is 6 meters, the space in which athletes must throw the ball to avoid penalisation, it is identified that the greatest velocity and speed is most important in the first few steps. Jorgic *et al*., (2019) identified that the results of the 5-meter sprint are indicators of speed abilities in Goalball players and the 10-meter sprint is a standard evaluation of sprint performance of athletes.

Atan and Ayca (2015) also investigated 10 metre sprint time in 19 VI athletes. They compared sprint times over a three-month period. Prior to testing, no significant differences were found between the exercise group and the control group. Following the three-month period completing Goalball training, sprint times were found to be decreased in the exercise group however values were unchanged in the control group. This identifies sprint time as being significant in Goalball performance seeing as Goalball alone can improve sprint times. It also implies that completing sport specific sprint training can have a further enhancement on Goalball performance. Therefore, these studies back up that sprint performance is an essential component of Goalball and training to improve sprint performance can enhance athletic performance.

5.3 Maximal strength

Another statistically significant characteristic of Goalball performance is maximal strength. This characteristic was identified as significant between the High-Performance and Talent athletes. The Academy athletes did not complete this test. As a matter of fact, research of the IMTP is limited if not non-existent in Goalball. This makes this piece of research unique to the fact it is feasible to complete the IMTP with athletes with VI. This is a novel finding that may guide future research especially seeing as Maximal strength was the most significant finding in this research (See Figure 3). The IMTP has been supported in dynamic testing due to the fact of many sports require multiple bio-motor abilities which can be tested through the IMTP, and this can be seen as advantageous due to its strong correlations to multiple dynamic sport assessments (Giles, Lutton and Martin, 2022). The IMTP has been confirmed as reliable and an efficient measure of maximal force generation capacity and rate of force development in athletes (Guppy *et al.,* 2018).

Suchomel, Nimphius and Stone (2016) completed a review previous literature on the effect of muscular strength on factors associated with athletic performance and the benefits of improving muscular strength. They identified that superior muscular strength has a strong correlation with increased force-time characteristics which can improve overall performance. They found stronger athletes have superior performance in competition and greater maximal strength which enhances movements such as jumping, sprinting and change of direction. Their results showed that there was no alternative for greater muscular strength when improving performance across universal and sport specific skills whilst also reducing injury risk whilst performing these skills. Sport practitioners should apply long term muscular strength training strategies to increase maximal strength within Goalball.

Healy *et al*., (2019) looked at the relationship between maximal strength and reactive strength measures in 40m sprint performance. 28 athlete's men and women at international and national level took part in the research. Part of the research consisted of athletes completing an IMTP. They found the IMTP was not significantly related to sprint performance measures, a factor we have found to be significant in this study. No relationship was identified between the IMTP and peak force, relative peak force and drop jump reactive strength index. This highlighted the high levels of maximal strength are not essential in achieving high reactive strength scores. It was noted that the sprint athletes most likely achieved higher reactive strength scores as a result of several years of sprint and plyometric training. They identified that the lack of association between maximal strength and sprint performance may be due to the delayed contact time comparative to sprinting and the failure to assess technical application of force.

Stone *et al*., (2003) researched the relationships between maximal strength and dynamic measures of performance in relation to throwing ability over an eight-week period. Eleven well trained college athletes took part in this research and athletes completed an IMTP to measure maximal strength. Their results suggested that an improvement in maximal strength can have a positive effect on peak power output in sport on both light resistance movements and heavy resistance movements. They explained that improving maximal strength can improve movements with very light or even zero resistance. For example, the transfer from defence to attack when the athlete goes from laying down to standing up in Goalball.

Stone *et al*., (2003) also explained that an improvement in maximal strength would likely contribute to the gains noted in power snatching, shot-puts and weight throws which can be related to Goalball in the attacking phase as the ball weighs 1.25 kg. Interestingly, their results showed the greatest increase in peak power during the first four weeks which is when the training emphasized maximal strength. Increases in isometric peak force indicated that as training went on, maximal strength was enhanced. An example being when throwing, being able to incorporate increased levels of maximal strength into the technique of the throw can aid performance and velocity. They concluded that isometric maximal strength is strongly related to the ability to generate peak force and peak power to help with dynamic explosiveness and they found with more training, the more these relationships improve.

5.4 Shoulder Strength

Shoulder strength was another statistically significant characteristic in Goalball. Both the left and right shoulder strength tests were significant between the High-Performance and Talent athletes and also between the High-Performance and Academy athletes. It was not significant between the Talent and Academy athletes. Interestingly, most research investigating shoulder strength in Goalball is limited and tests which investigate Goalball often measure throwing speed. This study is unique in the fact that the ASH test was used. Reliability was measured for this test using the intraclass correlation coefficient (ICC). The ASH test has been identified as a reliable test and can be measured using a Microfet (ICC = 0.77-0.99) or force plates (ICC = 0.94-0.98) which have a direct correlation with one another. Both devices are therefore reliable and valid ways to measure shoulder strength (Ashworth *et al.,* 2018; Krolikowska *et al.,* 2022).

Salles *et al*., (2015) investigated the effects of eight weeks of strength training on shoulder joint position sense and whether training intensity influenced joint position sense in regard to shoulder dynamic stabilizer muscles. This study used 90 right-handed men with no previous shoulder injury. Participants performed three strength training sessions per week focusing on the shoulder region. Pre-testing found no differentiation between groups however post testing a difference was noted. They found an interaction between groups and time. They explained strength training using exercises at the same intensity had a positive effect on joint position sense when compared with exercises of varied intensity. This suggested the consistent intensity improved sensitivity of muscle spindles and therefore better neuromuscular control was noted in the shoulder. This implies the importance of specific training to improve shoulder stability specific to sport. In Goalball this type of training will not only improve performance parameters via enhancing precision and accuracy which are dependent on high proprioceptive levels but also reduce the risk of injury.

Andrade *et al*., (2016) looked at the influence of fatigue on ball throwing velocity, shoulder strength and balance and throwing performance. Ten elite handball athletes were tested, and ball velocity was measured by radar gun. Athletes performed eight throws in standing and eight throws from a jumping position. Their study found internal and external rotators peak torque to be significantly lower following gaming activities. They also mentioned that ball throwing velocity was not affected by game activity and therefore fatigue had no effect on throwing performance. They did however find that simulated game activities had a higher effect on internal rotator strength than external rotator strength creating a muscle imbalance which could lead to injury. As those athletes with lower muscle strength have a higher chance of fatiguing earlier in performance, this suggests that shoulder strength did not have a large influence on throwing performance as players fatigued. Other factors should be investigated to identify if other power transference between the lower and upper limb can affect throwing velocity.

Chelly, Hermassi and Shepard (2010) investigated the relationships between power and strength of upper and lower limb muscles in throwing velocity of Handball players. Fourteen male handball players participated in this study. Players completed a maximal handball throw and bench press. A considerable relationship was noted between peak power of upper and lower limb muscles and throwing velocity. They identified that strength programmes should look at both the upper and lower limbs as lower limb strength can also have a positive effect on throwing performance. They recognised that upper limb strength has a dominant effect on throwing velocity of handball players.

5.5 Core stability

The final statistically significant characteristic in Goalball is Core Stability. Both left and right glute bridge tests were statistically significant. Interestingly, this result was not expected due to the fact the most significant grouping was between the High-Performance and Academy groups, the next significant finding was between the Talent and Academy groups however no significant finding was located between the High-Performance and Talent groups. It was expected that core stability would be the most significant in the High-Performance group, as it has been noted as a factor which has a significant impact on Goalball and most athletic performances. It is widely expected across all sports that the higher the athlete's performance level, the better they would perform physically. This can be seen visually from Figure 2. Core stability is essential to physical performance and can have a large impact on all other significant noted measures (Shoulder strength, Lower limb Power, Maximal strength and Sprint performance). Therefore, an important finding here is that the improvement of core stability may in fact enhance all other factors and improve success in competition. This reduction in core stability in the High-Performance athletes may be due to the fact that as athletes get older, core stability tends to reduce unless trained. This can be seen here as the younger Talent and Academy players have performed better in this test than the older High-Performance athletes. This therefore may be a characteristic which is not prioritised as much in training as other characteristics and has therefore deteriorated over time.

Mahrokh Moghadam, Zarei and Mahammadi (2021) used 26 elite Goalball players with B2 and B3 visual classifications. Participants took part in the functional movement screening test eight weeks apart to look at the impact of an eight-week core stability program on elite Goalball players. They split the group into an experimental and control group. The experimental group performed core stability training with a Swiss ball, three days a week for eight weeks. The control group continued with normal Goalball training. The results of the study showed a significant difference between the experimental and control groups ($p=0.021$). They suggested that motor function in Goalball players highlights the efficacy of this type of training in core stability muscles. They have suggested the use of core stability training as an efficacious way of improving movement patterns in Goalball players.

However, a systematic review by Reed *et al.*, (2012) evaluated 24 articles on core stability and an outcome related to sport. They found that core stability was used in comprehensive exercise programmes to look at skills such as vertical leaps and maximum jump load. Not all studies reported an increase in core stability measures following training programmes and investigations which primarily targeted the core as a goal for superior results of training had mixed results. They identified that core stability is infrequently the single component of athletic development making it challenging to isolate its effect on performance. They identified targeted core stability training supplied minor benefits to performance. This systematic review identifies only the one component of core stability on athletic performance. From our results we can see that core stability is in conjunction with many other characteristics which influence performance.

Research by Battaller-Cervero *et al.,* (2022) supports this finding. They looked at the evaluation of core stability as a variable which determines optimal throwing. Eight Goalball players were used in this study. Core stability was assessed completing a single leg thrust on a pressure platform maintaining each position for 10 seconds. They identified that core stability is an important factor related to throwing performance. They found core stability can improve precision and throwing performance in Goalball. Throwing performance is another variable we have found to be significant in this study and backs up what has previously been said as one characteristic cannot be a sole determinant of Goalball however when it becomes multifaceted, performance can in fact be affected by many characteristics.

5.6 Strengths

A cross-sectional study allowed for athletes to be tested on one occasion. This meant there was no need for any secondary testing sessions, which increased feasibility for players seeing as a lot of athletes had work commitments alongside Goalball which would have made it hard to complete testing across multiple sessions. This meant that more athletes were available to participate in testing. This design is a quick and inexpensive way to complete research, as well as the fact multiple outcomes can be measured and studied from one testing session (Wang and Cheng, 2020). This means an in-depth study can be produced from this. As Goalball athletes often have work commitments and due to their VI, it makes multiple testing sessions challenging especially seeing as this cohort can be hard to reach as they do not train on a regular basis to allow for multiple dates of testing. Due to the fact we are working with a hard-to-reach population, it was therefore agreed that cross-sectional testing would provide the most positive outcome for this thesis.

As previously mentioned, research in Goalball is limited and few papers investigate the physical and cognitive characteristics of Goalball. Therefore, this thesis incrementally adds to the limited research on Goalball. This is the first study which examines physical and cognitive characteristics discriminating against performance levels of Goalball. This is important as cognition and physical attributes are often reported to go hand in hand. This has been investigated in non-para sports, but research is yet to investigate the differences of cognition and physical characteristics on performance between levels of performance in Goalball. Therefore, although sample size may have been small, this study provides novel and unique findings which can aid performance criteria in Goalball and support further research.

5.7 Limitations

Participants used in this study were used from Goalball UK using their player performance level. Therefore, this study can only be generalized to UK based Goalball players and not the wider Goalball community internationally. Future research could look at Goalball on a wider scale across different athlete contexts. For example, in other countries Goalball players are full-time athletes. As such, the variability between groups would be less than more heterogenous samples. As well as this, sample size was relatively small due to using a small and challenging population which may have impacted results (25/31 UK Goalball Players). The issue with small sample sizes is the higher chances of type 1 and type 2 errors. This means a type 1 error may occur in which the null hypothesis is rejected in error and is stated that the finding is significant when that may not be the case. A type 2 error may occur when no differences or associations are declared between groups when there in fact was. The benefit of having effect sizes stated in this research means that some characteristics which were found to be non-significant may result in a significant finding if the sample size was larger and vice versa. However, although this sample size seems small, in comparison with other sports such as football and rugby and previous research, it is in reality a large sample size in terms of Goalball and representative of the available population, reaching 80.65% of players from Goalball UK Performance Pathway. Further studies with a larger sample size should be conducted to combat this and make results more meaningful, accurate and reliable. Future studies could also include other Goalball athletes, not just UK Goalball players to generalise the study to the general VI population as well as providing a larger base for more accurate results.

Results may well have not been as expected since Goalball UK athletes are not full-time athletes. In comparison with the UK, Goalball players from other countries are full time athletes who undergo regular strength and conditioning training and testing. For example, this may explain some of the large within group variability and limited difference across groups. Studying professional pathways may have less variability in physical and cognitive characteristics and have greater difference between groups in their respective Goalball pathway. As well as this, training rate does not differ much between levels of performance in the UK. This may not be the case in other countries. Therefore, we may expect better results and larger variability between levels of performance from these groups in comparison with Goalball UK. Further research should investigate these physical and cognitive characteristics in Goalball players who undergo different rates of training.

Furthermore, not all athletes completed every test. For example, Academy athletes did not complete Aerobic capacity testing or Maximal strength testing. This may have had a negative effect on results and may not have given a true representation of discrimination between levels. VI may have caused some fear and anxiety in participants which may have had a negative effect on results as participants may not perform to maximal potential. Testing should take place in familiar environments for participants to reduce this and testing should be completed on a regular basis to ensure participants are familiar with the tests they are completing with no allowance for error. Prior research in Goalball is limited. Had more research have been available this may have better influenced the tests performed by participants which may have been more bespoke to Goalball which may have resulted in more ecologically valid results. Future research should look to validate bespoke batteries of tests for VI populations to facilitate talent identification, talent development, and more reliable appraisal of athletes.

During this project, some key challenges were presented. This meant that some of the likely characteristics of Goalball were not tested due to the lack of time and space/resources available. Future testing could investigate the characteristics which were unable to be evaluated in this set of testing such as reaction time. Future studies could also challenge this research further by balancing reliable methods with ecologically valid methods for looking at creating a standard operating procedure for testing in Goalball. Conducting research within the Goalball environment can be challenging due to various factors as noted above. Therefore, research which can look at differences between levels of Goalball over a period of time may be beneficial to accurately measure the characteristics causing change within Goalball. Research can look at matching gold standard testing measures with accessible measures. Due to VI, athletes may require longer familiarisation periods, and this may differ amongst athletes, this could result in more reliable scores as fear and anxiety will not be overshadowing results. For example, the bike test was used in this research as it is a reliable measure of testing aerobic capacity and factors such as VI do not interfere as participants do not require any spatial orientation for this test. However, when performing Goalball, bikes are not used, and spatial orientation is key. Therefore, this test may not have been seen as ecologically valid to use within this population. A test which could have been performed for aerobic capacity would have been the 30-15, which can be adapted to pitch size. This test would have been more applicable to Goalball and replicable to a game situation. Due to concerns regarding athletes' spatial orientation this test was unable to be performed. Due to these reasons, testing had to be adapted to best fit the athletes with the time and resources available.

6.0 Conclusion

This study identified that Lower Limb Power, Sprint performance, Maximal Strength, Shoulder Strength and Core Stability all have a positive difference on goalball whilst Cognition, Muscular Endurance and Aerobic Capacity do not. This thesis highlights the importance of training physical characteristics which may be applicable to Goalball to enhance performance and help athletes to become elite in Goalball. As well as this, it may help coaches with which characteristics may influence the recruitment process across levels of performance and to help them to implement training plans to optimize performance and to have the most successful team possible. Further research is required to look deeper into these characteristics on a larger scale to increase the generalization of results. Higher sample sizes may have a more positive difference on results as well as ensuring all levels of performance conduct each test to see if there is a significance between more groups which was not possible in this thesis.

7.0 Appendices

7.1 Scat 6 Part 3

Orientation:

What month is it?	0	1
What is the date today?	0	1
What is the day of the week?	0	1
What year is it?	0	1
What time is it right now? (within 1 hour)	0	1
Orientation Score:		_ out of 5

Immediate memory:

Trial 1 say: I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order.

Trial 2 and 3 say: I am going to repeat the SAME list. Repeat back as many words as you can remember in any order, even if you said the word in the previous trial.

List A	Alternate list B	Alternate list C	Trial 1	Trial 2	Trial 3
Jacket	Finger	Baby	0 / 1	0 / 1	0 / 1
Arrow	Penny	Monkey	0 / 1	0 / 1	0 / 1
Pepper	Blanket	Perfume	0 / 1	0 / 1	0 / 1
Cotton	Lemon	Sunset	0 / 1	0 / 1	0 / 1
Movie	Insect	Iron	0 / 1	0 / 1	0 / 1
Dollar	Candle	Elbow	0 / 1	0 / 1	0 / 1
Honey	Paper	Apple	0 / 1	0 / 1	0 / 1
Mirror	Sugar	Carpet	0 / 1	0 / 1	0 / 1
Saddle	Sandwich	Saddle	0 / 1	0 / 1	0 / 1
Anchor	Wagon	Bubble	0 / 1	0 / 1	0 / 1
Total			/ 10	/ 10	/ 10

Concentration:

Administer at the rate of one digit per second reading down the column. If a string is completed correctly, move on to the string with the higher number of digits; if the string is completed incorrectly, use the alternate string with the same number of digits. If the participant fails again, end the test.

Say*: I'm going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. E.g. if I say 7-1-9 you would say 9-1-7.*

List			
4-9-3 6-2-9	Y Y	N N	0 / 1
3-8-1-4 3-2-7-9	Y Y	N N	0 / 1
6-2-9-7-1 1-5-2-8-6	Y Y	N N	0 / 1
7-1-8-4-6-2 5-3-9-1-4-8	Y Y	N N	0 / 1

Digit score / 4

Months in reverse order:

Say: *Now tell me the months of the year in reverse order as quickly and accurately as possible. Start with the last month and go backward. So, you'll say December, November… go ahead.*

December November October September August July June May April March February January

Time taken (secs) No. of errors:

1 point if no errors and completion under 30 seconds.

/ 1

Total concentration score (Digits and Months) / 5

Table 4: Scat 6 Part 3.

7.2 Signed Gate Keeper Form

Chloe Smith

Masters by Research

York St. John University

School of Science, Technology & Health

Haxby Road Sports Park

York

YO31 8TA

chloe.smith6@yorksj.ac.uk

Dear Faye,

As part of my postgraduate degree, I am completing a research project Describing the Physical and Cognitive Determinants of Performance in Goalball players. I request your permission to use your organisation to complete my research study.

What does the study involve?

The study will look at examining the physical characteristics it takes to be an elite goalball player and whether these are influenced by an athlete's cognitive ability and if this discriminates between athletes at differing levels of performance. This will be a physical intervention in which athletes will perform a number of assessments that investigate their physical and cognitive performance levels. I have included further information about the study in the accompanying Participant Information Sheet.

What happens with the study findings?

Only my dissertation supervisor and I will have access to the information from this investigation. All information will be stored in line with the requirements of the General Data Protection Regulation (GDPR). Pseudonyms will also be used to protect the anonymity of all participants, people and organisations who take part in the study.

Who can I contact if I have any questions?

My details are at the top of the page. Alternatively, you can contact my supervisor:

Dale Forsdyke

School of Science Technology and Health,

York St John University,

Lord Mayor's Walk,

York,

YO31 7EX.

Email: d.forsdyke@yorksj.ac.uk

Jamie Salter,

School of Science Technology and Health

York St John University,

Lord Mayor's Walk, York,

YO31 7EX

Email: j.salter@yorksj.ac.uk

If you have any concerns, queries or complaints regarding the research project please contact Dr Charlotte Haines-Lyon, Chair of the Ethics Committee for the School of Education, Language and Psychology' Email c.haineslyon@yorksj.ac.uk.

You may also like to contact the University's GDPR contact to discuss any questions or concerns related to this project:

us@yorksj.ac.uk (University Secretary).

Thank you for taking the time to read this information.

Yours sincerely,

Chloe Smith

Masters by Research, York St John University.

Please sign below if you are happy for me to complete my research in your organisation.

I have read and understand the above information and **do give my consent** to this study taking place.

Print Name: ...Faye Dale………………………………………… Date: …….26th June 2024…………………………

Signature: *..FDale*…………………………………………………………

7.3 Blank Participant Information Sheet

Name of school: School of Sport, York St John University

Title of study: Describing the Physical and Cognitive Determinants of Performance in Goalball players.

Introduction

You have been invited to take part in a research project examining the physical characteristics it takes to be an elite goalball player and whether these are influenced by an athlete's cognitive ability and if this discriminates between athletes at differing levels of performance. Before you decide whether or not to take part, it is important that you understand why this research is being done and what it will involve. Please take time to read this information carefully and discuss it with others if you wish. If there is anything that is unclear or if you would like more information, please contact me (Chloe Smith, postgraduate student in the School of Sport, York St John University) or my supervisors (Dale Forsdyke or Jamie Salter, School of Sport, York St John University) using the contact details on the following page.

What is the purpose of this investigation?

The aim of this investigation is to examine what physical characteristics make up an elite goalball player and whether cognitive characteristics have an effect on athlete's physical capabilities. In conducting this investigation, I am trying to raise awareness of the physical characteristics it takes to become elite within goalball and expand the research within the area of goalball.

What will you do in the project?

Part of this study involves physical testing with male and female goalball athletes at international, national and recreational levels in order to gain sufficient evidence to discover the main physical characteristics within goalball. You will be asked to take part in 6 different tests, which will be based around the main physical and cognitive areas of goalball.

Do you have to take part?

No. It is up to you to decide whether or not you would like to take part in this study, but your contribution would be greatly appreciated. You will not be treated any differently, whether you choose to take part, or decide not to do so. If you do decide to take part, you may later withdraw from the study without giving a reason and without penalty.

Why have you been invited to take part?

You have been invited to take part in this project because you are an international, national or recreational goalball player, having played for a minimum of one year.

What are the potential risks to you in taking part?

There are minimal risks to taking part in this study beyond those of which you normally come across in Goalball. All tests will have been adapted to fit athlete's needs. You do have the right to withdraw from this project at any point, without giving a reason. You can withdraw from the project by informing me (the researcher) via email that you wish to do so and quote your unique code. If you withdraw from the research, any data recruited from you will be removed from the data that has been collected. You may request that the information you have provided be removed from the study at any point until the data has started to be analysed. This means that you can request that your data be removed from the investigation until four weeks (28 days) after the date that you took part in the study.

What happens to the information in the project?

All testing will remain confidential. Pseudonyms will be used for you and any people that you mention in order to maintain anonymity. All data collected whilst conducting this investigation will be stored securely on a password protected computer account and further protected on the password protected OneDrive storage system, which is used for the storage of research data at York St John University, in line with the requirements of the General Data Protection Regulation. The information collected whilst conducting this project will be stored for a minimum of 6 months.

Thank you for reading this information – please ask any questions if you are unsure about what is written in this form.

What happens next?
If you are happy to take part in this project, you will be asked to sign a consent form to confirm this.

It is possible that the results of this research project will subsequently be published. If this is the case, appropriate steps will be taken to ensure that all participants remain anonymous.

If you do not want to be involved in the project, I would like to take this opportunity to thank you for reading the information above.

Researcher contact details:

Chloe Smith – Lead Post Graduate Student Researcher chloe.smith6@yorksj.ac.uk

Dale Forsdyke – Supervising Lecturer d.forsdyke@yorksj.ac.uk

Jamie Salter – Supervising Lecturer j.salter@yorksj.ac.uk

University Details:

School of Sport

York St John University

Lord Mayor's Walk

York

YO31 7EX

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought, please contact:

Dr Sophie Carter

Chair of the Ethics Committee for the School of Science, Technology and Health

York St John University,

Haxby Road,

York, YO31 8TA

Email: s.carter@yorksj.ac.uk

Consent Form

Name of school: School of Sport, York St John University

Name of researcher: Chloe Smith

Title of study: Describing the Physical and Cognitive Characteristics of Goalball.

Please read and complete this form carefully. If you are willing to participate in this study, please circle the appropriate responses and sign and date the declaration at the end. If there is anything that you do not understand and you would like more information, please ask.

- I have had the research satisfactorily explained to me in written form by the researcher. **YES / NO**
- I understand that the research will involve physical and cognitive tests **YES / NO**
- I understand that I may withdraw from this study at any time without having to give an explanation. This will not affect my future care or treatment. I understand that I should contact you via email if I wish to withdraw from the study and that I can request for the information that I have provided to be removed from your investigation for a period of four weeks (28 days) after the date that I took part in your study. **YES / NO**
- I understand that all information about me will be treated in **YES / NO**

strict confidence and that I will not be named in any written work arising from this study.

YES / NO

- I understand that you will be discussing the progress of your research with your research project supervisor at York St John University. **YES / NO**

- I consent to being a participant in the project.

Print Name:	Date:

7.4 Supervision Log

RESEARCH STUDENT SUPERVISION LOG

Student Name:			Chloe Georgina Smith	Student Number:	209082551
Supervisory Team (including external members):			Dr Jamie Salter Dr Dale Forsdyke		
Degree:			MSc by Research (FT)	Start Date:	01/10/2023
Supervision Number	**Date of Meeting**	**People Present**	**Main Topics Discussed**	**Action Points Agreed**	**Targets for Next Meeting**
1	17/10/23	Chloe Smith Dale Forsdyke Jamie Salter	Research question topic Types of testing Induction questions	Research area of interest Start planning a method	
2	07/12/23	Chloe Smith Dale Forsdyke Jamie Salter	Accessibility of consent forms for VI people. Methods – tests, where, when, who. Ethics	Plan which tests to use. Organise testing day. Contact Goalball teams. Begin introduction ideas. Complete ethics.	Complete methods draft / bullet points for intro.
3	Jan / Feb?	Chloe Smith Dale Forsdyke Jamie Salter	Bullet pointed introduction Discussed booking equipment Discussed methods (tests / participants)	Book equipment for testing Carry on with methods/intro	Have equipment booked Have initial drafts of methods/intro complete
4	14/03/24	Chloe Smith Dale Forsdyke Jamie Salter	Discussed structure of mid-point review Discussed testing days Discussed data analysis	Update methods / introduction drafts	Updated methods / introduction drafts after feedback.
5	25/04/24	Chloe Smith Dale Forsdyke Jamie Salter	Discussed ethics Methods and Intro improvements	Complete ethics submission Improve methods and intro/lit review	Methods completion Ethics confirmed
6	03/06/24	Chloe Smith Dale Forsdyke Jamie Salter	Testing discussion Equipment discussion	Organise data testing days Edit ethics due to changes in research	Update ethics Data sessions confirmed
7	18/07/24	Chloe Smith Dale Forsdyke Jamie Salter	Testing discussion Intro and lit review discussion	Complete data testing	Complete data testing
8	11/09/24	Chloe Smith Dale Forsdyke Jamie Salter	Data discussion	Input data to master sheet Continue lit review	Have data ready for analysis
9	08/10/24	Chloe Smith Jamie Salter	Data analysis and inputting Writing structure for results and discussion section	Complete results section Begin discussion	Have results and data analysis complete.
10	06/11/24	Chloe Smith Dale Forsdyke	Discussed drafts of methods/results Formatting	Send draft of thesis for improvements	Complete full draft of paper
11	12/12/24	Chloe Smith Dale Forsdyke Jamie Salter	Discussion section improvements Strengths and limitations improvements	Complete improvements	Complete improvments
12	13/12/24	Chloe Smith Dale Forsdyke	Finalised final follow up points for improvements	Complete final improvements. Upload thesis.	-

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